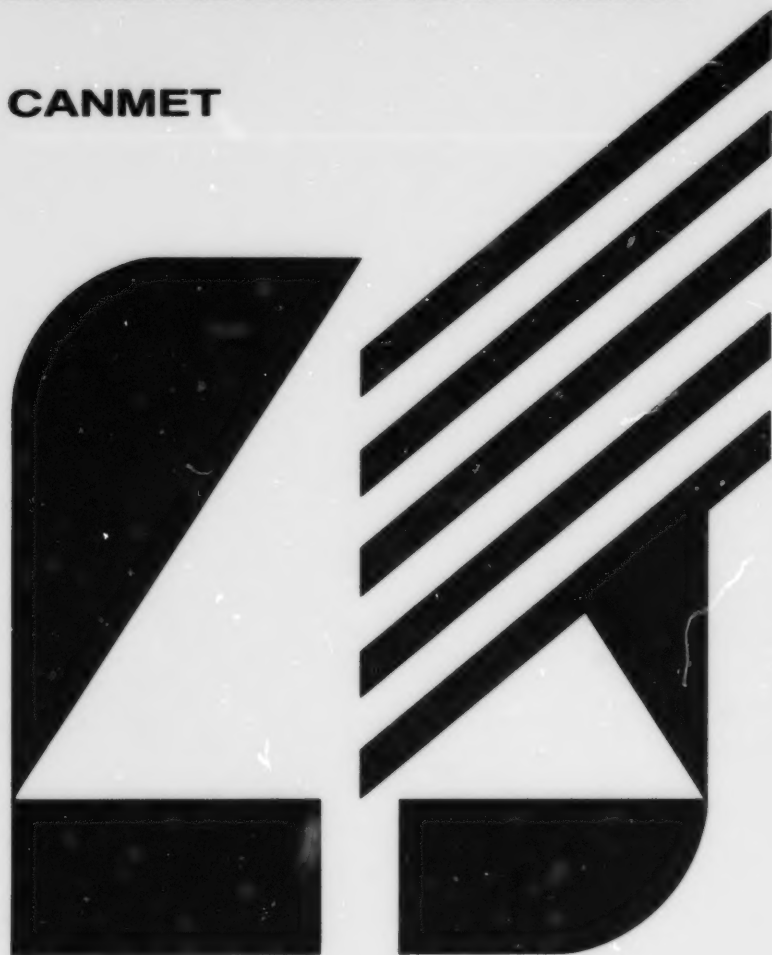


CANMET



Bioenergy



Energy, Mines and
Resources Canada

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Ressources Canada

Canada

THE ENERGY OF OUR RESOURCES

THE POWER OF OUR IDEAS

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BIOENERGY PROJECTS DIGEST
COMBUSTION
1984-1989

*A review of Bioenergy Combustion
research and development projects
funded by Energy, Mines and Resources*

September 1990

99 PP

Bioenergy Projects Digest

Combustion

Funding for these projects was provided in part by the Federal Panel of Energy R&D,
Energy, Mines and Resources Canada



Preface

The Bioenergy Projects Digest/Combustion is part of a series of four progress reports which review and update current and completed bioenergy projects funded by Energy, Mines and Resources Canada, and through the Panel of Energy Research and Development (PERD).

The Bioenergy Development Program at EMR supports research, development, demonstration and installation projects that are environmentally safe, encourage industrial development and export opportunities and, most importantly, can yield a growing contribution to Canada's energy supply. In addition to Combustion, EMR also provides support for the technological development of Materials Handling, Biochemical and Thermochemical Conversion technologies.

This digest traces a brief historical and technical perspective of these technologies in Canada and contains 36 project summaries. A contractor index in the final pages of the document provides further assistance in locating specific project summaries.

Companion documents to this publication include Bioenergy Projects Digests for Materials Handling, Thermochemical Conversion, and Biochemical Conversion. To obtain a copy of any or all of these publications, readers are invited to fill out the order form at the end of the digest and send it to the address provided. These publications reflect the growth of bioenergy in Canada and how it is fostered by a partnership between government and industry.

The Bioenergy Projects Digests will provide a useful compendium of current technology development in Canada. To ensure that readers are kept abreast of achievements in this field, this document will be updated on an ongoing basis.



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Bioenergy Projects Digest Order Form

INTRODUCTION TO BIOENERGY

TECHNOLOGY DESCRIPTION

In its broadest sense, the term **BIOENERGY** refers to all of the activities associated with the collection of raw biomass feedstocks to their processing into prepared biofuels, their conversion to useful energy, and the use of this energy. **BIOMASS** refers to all organic plant and animal matter. The **BIOENERGY RESOURCE** can be defined as the portion of available biomass which is not used as food or other high-value traditional products, and is recoverable without causing a significant negative environmental impact. Major components of this resource comprise the following:

- Primary wastes, residues, residuals and by-products from traditional industrial activities directly associated with the forestry and agrifood sectors. These include forest residuals (logging slash, non-merchantable trees, salvage and land clearing residues, sort-yard debris), mill residues (bark, sawdust, shavings, solid trim, sludges and clarifier effluent, spent pulping liquors), crop residuals (straw, stovers, prunings), animal by-products (manure, litter, blood and fat), and food processing residues (grain screenings, culls, pits, pomace, whey, fish oil, coffee grounds, etc.)
- Secondary wastes from domestic, commercial and industrial processing or utilization of biomass-derived materials or products. These include municipal solid wastes (MSW)(paper, cloth, grass clippings, leaves, leather, rubber, food residues, etc.), sewage and sewage sludge, and commercial and industrial wastes (cardboard, paper, textiles, demolition wood, packaging materials, etc.)
- Dedicated energy crops grown on surplus land areas, including plantations (trees, brush), energy crops (kochia, milkweed, artichokes) and traditional crops (starches, sugars, oilseeds, etc.)
- Non-horticultural peat deposits.

These biomass feedstocks can be converted to useful energy in a number of different ways. They may be utilized in direct combustion applications for the production of thermal, mechanical or electrical energy. Alternatively, they can be upgraded or converted to prepared **BIOFUELS** that are a direct substitute for traditional fossil fuels. These biofuels include solid prepared fuels, such as wood chips and Refuse Derived Fuels (RDF), that have been subjected to relatively minor physical preparation, or those produced through significant physical and/or thermochemical treatments, such as charcoal, K-fuel or Densified Biomass Fuel (DBF). Biofuels also include liquid or gaseous fuels produced by major thermochemical and/or biochemical conversion processes, such as alcohols, methane or bio-oils.

Several sub-groups within the category address specific process operations associated with the conversion of bioenergy feedstocks to useful energy.

1) Materials Handling

Materials handling is a broad category which covers mechanical biomass feedstock manipulation and preparation, without significantly altering the chemical or biochemical characteristics of the feedstock. Sub-components include the following:

- harvesting, collecting, accumulating
- moving, storing, measuring, metering, feeding
- beneficiating (segregating, mixing, comminuting, drying, compacting)
- extracting (mechanical, chemical)

2) Combustion

Combustion is defined as the rapid high-temperature oxidation (burning) of solid, liquid or gaseous biomass or biofuels to provide thermal, mechanical or electrical energy. Traditionally, the application of biofuel-derived energy to a specific load is included as well as the actual combustion system. In practice, a major breakdown is used:

- Small-scale, less than 10 GJ/h, usually residential systems, and small commercial, institutional and industrial systems which provide space heating, hot water and limited process heat loads.
- Medium-scale, 10-40 GJ/h, typically large institutional and industrial systems which provide process heat with limited space heating, and occasionally electrical energy.
- Large-scale, greater than 40 GJ/h, typically very large packaged or field erected boilers in the industrial sector (principally pulp and paper and Energy-from-Waste [EFW] facilities) which provide high-pressure process steam very often with associated co-generation of electricity.

3) Thermochemical Conversion

Thermochemical conversion refers to processes in which biomass feedstocks undergo irreversible chemical changes through reactions that are principally driven by the action of heat (thermal energy). Sub-categories include gasification, in which the primary product is a gas; liquefaction, in which the primary product is a liquid; and carbonization, in which the primary product is a solid char.

4) Biochemical Conversion

Biochemical conversion pertains to operations in which a biomass feedstock is converted by a living organism (eg. fermentation by yeasts), or by an agent produced by a living organism (eg. enzymatic conversion), into a product whose chemical properties are different from the feedstock. Sub-technologies include bio-gasification, bi-liquefaction and various pretreatments.

In addition to the basic technology groups associated with preparation or use of biofuels, two categories exist which are not directly associated with energy.

i) Chemicals

The production of chemicals from biomass where the chemicals are traditionally produced from fossil fuels. Biomass thus displaces petroleum and natural gas as a petrochemical feedstock, releasing these high-value fuels for other applications.

ii) *By-products*

Efforts to develop by-products that, in themselves, have no direct energy implication are of interest since the production of high value saleable co-products can make a bioenergy process more economically attractive.

HISTORICAL PERSPECTIVE

At the time of Confederation in 1867, energy supply in Canada was based almost exclusively on bioenergy: only about 10 per cent was obtained from non-biomass sources such as coal and waterpower. However, by that time bioenergy was already in decline, and just before 1900, coal achieved a market penetration equivalent to that of biomass. The sale of biofuels continued to drop steadily as coal, and subsequently oil became the fuels of choice. By the early 1970s, bioenergy contribution had decreased to only about 3 per cent of the national energy supply, based primarily on the combustion of spent liquor and hog fuel in the pulp and paper industry.

Abrupt world oil price escalation during the late 1970s ushered in an energy-crisis decade during which bioenergy notably recovered. Market penetration more than doubled to over 7 per cent of total energy supply before oil prices slumped in the mid-1980s. While biofuel use in the residential and industrial sectors has decreased to some extent in the last decade, overall consumption has remained relatively stable, with increased activity in some market sectors.

More stringent environmental controls on landfilling of wastes have enhanced the economic desirability of utilizing Municipal Solid Wastes (MSW), sewage sludges and secondary forest industry residues in efficient energy recovery systems. Also, the regional social benefits of bioenergy have ensured continuing support for bioenergy installations in the institutional sector (eg. schools, hospitals and public facilities), particularly in the Atlantic region where natural gas is not available and electrical energy is expensive compared to other regions of the country.

It has been estimated that current biofuel use provides at least 600 PJ/y of energy in Canada. This is derived from forest industry residues (380 PJ/y), firewood and fuel chips (200 PJ/y), and MSW/sewage (30 PJ/y). The theoretical potential of the Canadian bioenergy resource is estimated to be in excess of 12,000 PJ/y; however, only about 1,800 PJ/y is assumed to be practically available on a non-crisis basis. This net increment would allow a potential increase in bioenergy supply to over 20 per cent of present Canadian energy demand.

INTERNATIONAL PERSPECTIVE

Less than 1 per cent of the annual biomass growth worldwide, is utilized for energy, but it provides about 15 per cent or roughly 48,000 PJ/y of total primary energy. In many developing countries, biomass is the major energy source, contributing, for example, nearly 100 per cent of their energy supply in Nepal and Ethiopia, 50 per cent in India, 33 per cent in China, and 25 per cent in Brazil.

In a number of countries, particularly in Europe, problems associated with waste disposal in heavily populated centres, depleting fossil fuel resources, and strong government commitments to indigenous energy use have created a significant market for bioenergy systems. Canadian suppliers are addressing this market niche, and exports have been achieved in the areas of anaerobic digestion, fast pyrolysis, direct combustion and in materials handling applications.

Canada is also very active in cooperative international bioenergy initiatives through bilateral agreements on science and technology (USA, European Economic Committee [EEC], Sweden, Japan) and participation in the International Energy Agency (IEA) R&D agreement on bioenergy. EMR is involved in several of the IEA Bioenergy Conversion Task activities, including thermal liquefaction, municipal solid waste, gasification, conversion data bases, combustion, standard analytical methods and bioconversion of lignocellulosics. Forestry Canada participates in two other IEA Tasks, Biomass Production and Biomass Harvesting/Transportation.

CANADIAN ACHIEVEMENTS

Bioenergy has been re-established as a significant contributor to the Canadian energy supply sector. Energy from biomass is now roughly half that derived from coal, and approximately equal to that of the nuclear industry. On a regional basis, bioenergy is far more significant: in the Atlantic region it contributes 12 per cent of the energy supply, and 23 per cent in British Columbia.

Almost 40 per cent of Canadian households burn wood for a portion of their space heating requirements. Firewood consumption is 11 million oven dry tonnes (ODT) per year, or roughly 12 per cent of total roundwood harvest, displacing an estimated \$1 billion in conventional fuels each year.

Bioenergy use now extends beyond its more traditional uses. It has been introduced, established, and accepted within segments of the commercial, institutional and small industrial sectors. Particular success has been achieved in greenhouse heating, health care facilities (hospitals, old-age homes and nursing homes), and educational facilities (schools, universities and colleges). Bioenergy has successfully penetrated a wide range of diverse markets, including stores, motels/restaurants, garages, workshops and office/apartment buildings. In the large industrial sector, biofuel use has been adopted in automobile manufacturing, textile, cement, and food processing industries.

A biofuel supply infrastructure has been established in many areas including firewood processors/suppliers, whole tree fuel chip producers, wood residue brokers/distributors and both large and small-scale wood pellet plants.

The supply of bioenergy equipment is a significant component of Canadian manufacturing activity. Over 100 firms are involved in the supply of combustion systems, generating annual sales in the order of \$200 million.

The past decade of intensified bioenergy activity has established Canada as a world acknowledged expertise in the technologies associated with the production, conversion and utilization of indigenous biomass resources for energy. This position is based on:

- an established core of individual expertise within the bioenergy community which is composed of government research scientists, university professors and a wide cross-section of engineers and scientists working in the private sector;
- a computer network-linked group of laboratories with facilities for bench-scale research, as well as specialized capabilities such as extensive analytical capabilities based on state-of-the-art equipment; standardized combustion facilities for testing and certification; and continuous process development units for feedstock evaluation and process optimization;

- a number of full-scale, field-installed, commercial prototypes which are continuously monitored for performance, and several mobile test reactors for site evaluations.

CURRENT PROGRAMS

The Interdepartmental Panel on Energy Research and Development (PERD) was formed in 1975 to review, assess and allocate funds to federal energy R&D and to develop tasks and programs to be managed by selected federal departments and agencies with expertise in various technical areas. The Canadian Forestry Service launched the five year, Energy from the Forest (ENFOR) program in 1978, which was divided into two main sub-programs: biomass production and conversion. Other departments also added modest bioenergy R&D components to their existing programs.

In 1984, the National Research Council withdrew from the energy program, Agriculture Canada phased out its program, and Energy, Mines and Resources (EMR) assumed the lead in bioenergy activities. With the transfer of the ENFOR program to EMR from the Canadian Forestry Service EMR established the Bioenergy Development Program (BDP).

In 1988, a new policy measure, called Energy Efficiency and Diversity (EED), was announced, based on three broad overall objectives:

- to enhance Canada's industrial competitiveness;
- to improve the quality of the environment; and
- to ensure Canada's energy security.

Under this policy, the BDP placed increased emphasis on commercially-oriented R&D to provide technologies that will become market competitive as the demand for diverse, secure, and environmentally sustainable energy sources intensifies.

In 1989, CANMET introduced a three-year business plan under which the Efficiency and Alternative Energy Technology Branch (EAETB) will continue to address the general R&D objectives within the broad program categories of:

- strategic research and development which covers large-scale, long-term research, development and pilot demonstration projects that establish and sustain CANMET's existing technology base;
- incremental research and development projects of a short-term nature that extend and improve existing industrial technologies and knowledge;
- mandated and specialized services performed under legal obligation or because of unique CANMET facilities or expertise;
- exploratory basic research that is relevant to CANMET's mission, but not sponsored by outside clients.

With these objectives, federally funded bioenergy R&D spans the entire R&D spectrum, from fundamental and applied research through to near-term development. For technologies that are targeted for near-term commercialization, private sector cost-sharing is practiced, typically ranging from 25 to 75 per cent contribution or more, depending on the proponents' plans to scale-up the process, the degree of technical risk and the expectations of the private sector to acquire a licence to commercialize the technology.

The level of effort allocated to a specific bioenergy resource has assumed proportions appropriate to the opportunity for that resource to contribute to Canada's energy supply. The measure of opportunity takes into consideration factors such as the time frame for commercialization, realizable near and long-term market uptake, national versus regional potential, national environmental priorities, and other economic, social, industrial or employment benefits.

FUTURE DIRECTIONS

With the rapidly evolving technical advances in biomass fractionation processes, a new world of product opportunities is opening up based on the concept of a "bioenergy refinery". This approach would separate raw feedstocks into the main component streams of cellulose, xylans, lignin and extractives, and selectively convert these intermediates to a wide slate of value optimized fuels, chemicals and specialty products.

The continuing EMR program in bioenergy will emphasize commercially-oriented research, development and technology transfer that will enhance the competitiveness of Canadian industry and provide a secure, more diverse energy base while contributing to an overall improvement in the environment. Efforts will be devoted to the development and implementation of standards for performance, safety and emissions, and support for research activity to establish uniform feedstocks, analytical procedures and product evaluations.

R&D PROJECT SUMMARIES

General Studies



Bioenergy Fact Sheet

STUDIES SERIES

Bioenergy Installations and R&D: A Database

Principal Investigator

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Study Objectives

The overall objective of this study is to improve both the information available regarding bioenergy technology and the efficiency of retrieval of that information. This was accomplished by the design and implementation of a unique bioenergy database that includes high quality, validated information on bioenergy installations, bioenergy R&D and sources of bioenergy products and expertise in Canada. The database -- known as the Bioenergy Information and Technology Transfer System or BITTS -- can produce the various outputs that will be used to encourage expanded use of appropriate bioenergy technologies. Marbek Resource Consultants Ltd. and Ensyn Engineering Associates Inc., were responsible for conducting this project.

START DATE:	01/88
COMPLETION DATE:	03/89
APPLICABILITY:	
Industrial sector	Agricultural sector
Commercial sector	Institutional sector
TYPE OF BIOMASS:	
Not specific to a type of biomass	
TYPE OF TECHNOLOGY:	
Not specific to a technology	
TOTAL STUDY COST:	\$190,304 (estimated)

Background and Method

In recent years, substantial federal and federal/provincial funds have been expended in support of bioenergy projects, through incentive programs, demonstration programs, and R&D support. These initiatives have produced a vast resource of information.

To date, dissemination of this information has been limited. Accordingly, attention in CANMET/Energy, Mines and Resources (EMR) has shifted to the need for expanded technology transfer efforts designed to encourage and facilitate additional bioenergy use in a wide variety of sectors. The benefits of such a technology transfer program are expected to be significant.

The BITTS system will be a key tool in this effort. When complete, it will consist of:

(1) Bilingual records on hundreds of installations and studies plus an extended list of sources of products and expertise -- all to be regularly updated, and

(2) Customized software capable of producing, for instance, publication-quality factsheets on individual installations and studies; directories of installations and/or R&D meeting specified search criteria; and managerial reports which aggregate and compare data.

In addition to Marbek Resource Consultants and Ensyn Engineering, contributors to the project include the Biomass Energy Institute, Capital Software, and David A. Newton.

Bioenergy Installations and R&D: A Database

(continued)

Results

Phase I in the development of BITTS will be complete in March 1989. At that time, most of the major software capabilities will be in place, requiring minor refinement only. In addition, some 200 installations and about 165 R&D projects will be in the system, awaiting finalization. A further 130 R&D projects will also be documented based on a reduced data gathering effort.

The remaining tasks in the development of BITTS were expected to take place in Phase II, scheduled for completion by the end of 1989 (although a wide range of outputs from the system will be available in mid 1989).

Initially at least, access to BITTS will be restricted to authorized users. However, BITTS outputs will be freely available on request, and will be distributed pro-actively by EMR. In the longer term, on-going maintenance of the database by EMR is considered a high priority, to maintain the value of the information provided.

Publications

(1) G. Matheson, SEVENTH CANADIAN BIOENERGY R&D SEMINAR, An Introduction to the Bioenergy Information Technology Transfer System (BITTS), MARBEK Resource Consultants, 1989, pp. 727.

Sources of outside financial support for this study included:

Source: EMR
Program: BDP
Proj. No: 7-6044
Value: \$190,304

Scientific Authority: Dr. W.E. Lowe

Funding for R&D supported by the Bioenergy Development Program (BDP) was provided by the Interdepartmental Panel on Energy R&D (PERD).

This fact sheet is one of a series. The information has been carefully checked and has been verified at source. The information presented was current as of:

12/07/90

All fact sheets in this series are prepared using a computerized database, the Bioenergy Information and Technology Transfer System (BITTS).

For further information, contact the Efficiency and Alternative Energy Technology Branch, EMR Canada 580 Booth Street, Ottawa K1A 0E4.

Energy, Mines and Resources Canada/CANMET



Bioenergy Fact Sheet

STUDIES SERIES

Bioenergy Simulation Program (BIOSIM)

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Study Objectives

The overall objective was to develop a computer model for predicting the economics of producing energy and prepared fuels from biomass. Specific objectives were the following: to utilize the database developed under ENFOR C-258 which delivers the performance and cost of energy system components; provide a means for developing process and system layouts for specific situations while permitting on-line interaction with the user; produce a program to estimate the performance and cost of alternate energy systems; provide a means for conducting sensitivity analyses on various processes and systems; and to provide a means for examining market penetration of biomass energy.

START DATE:	06/84
COMPLETION DATE:	05/89
APPLICABILITY:	Industrial sector
TYPE OF BIOMASS:	Mill or factory waste
TYPE OF TECHNOLOGY:	Not specific to a technology
TOTAL STUDY COST:	\$264,975 (actual)

Background and Method

Wood residue fuels are used extensively in the forest products industry to generate steam and electricity. Considerable potential exists for expanded use of forest biomass as fuel in these as well as other industry sectors. A computer model was developed in 1986 (in a joint venture by B.H. Levelton & Assoc. Ltd. and H.A. Simons Ltd.) to simulate steady-state performance and estimate capital and operating costs for biomass energy systems. The bioenergy simulation model (BIOSIM) was developed on a DEC VAX 780 computer. To encourage widespread use of the model by industry and government, BIOSIM was made available on micro-computer.

Systems which may be simulated and costed by BIOSIM are organized by energy output. A system for production of a specific energy product and specific type of equipment are stipulated by the user in a systematic fashion by choosing from simple menus presented in a logical order by the model. Once these steps are completed, the menus prompt the user for data defining the type and properties of the feedstock to be used. The menus then deal with handling, preparation and storage of the feedstock in the plant. The menu concludes with requests for specific unit cost data for feedstock, various supplies used by the system, and utilities. The equipment and data selection are aided by comments included in the menus explaining some of the options available.

Bioenergy Simulation Program (BIOSIM)

(continued)

Results

BIOSIM simultaneously calculates material flows, sizes equipment and estimates capital and operating costs for simple or complex biomass energy systems using interactive input from the user. A simulation program, MASSBAL, is used to solve the set of equations defining the performance and cost of unit processes forming the energy system. Advantages of using BIOSIM for studies are the following: performance and cost estimates may be done rapidly at low cost, encouraging a more thorough consideration of system alternatives and offering the opportunity to identify the optimum design; rigorous sizing and costing of equipment can be done easily and quickly; performance and cost data for unit processes can be kept up-to-date easily; unit processes may be customized by the user to reflect special knowledge, proprietary designs, specific cost information, etc.; and costs, feed materials and products are summed automatically for easy reporting or transfer to an economic analysis spreadsheet.

Because of the generality of the design of the BIOSIM FORTRAN programs and the keyword interpretive programming which can be added to the menus and simulation modules, BIOSIM could be readily adapted for analysis of other complex systems. For example, BIOSIM could be adapted for analysis and costing of production plants in the chemical and forest products industries.

Publications

(1) W.C. Edwards and L. Wasik, PULP & PAPER CANADA, 90:1, Biomass to Energy Conversion: Process and Economic Simulation on a Personal Computer, 1989, pp. 148-153. (2) W.C. Edwards and J.F. Wong, COST ENGINEERING, Vol. 29, no. 10, A Computer Model to Estimate Capital and Operating Costs, Oct. 1987. (3) W.C. Edwards and L. Wasik, SIXTH CANADIAN BIOENERGY R&D SEMINAR, Biosim - An Interactive Simulation Model for Costs of Wood Energy Systems, B.H. Levelton & Associates Ltd., 1988, pp. 219-223. (4) W.C. Edwards, T. Cotton, L. Wasik, J.F. Wong, DEVELOPMENT OF A COMPUTER MODEL TO SIMULATE BIOENERGY CONVERSION SYSTEMS: VOLUME I MODEL DESCRIPTION AND USER MANUAL, Bioenergy Development Program No. 4-5010A, Energy, Mines and Resources.

Sources of outside financial support for this study included:

Source:	EMR	EMR
Program:	BDP	BDP
Proj. No:	5-7021	6-6187
Value:	\$130,122	\$107,153

Scientific Authority: E.N. Hogan

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For further information, contact the Efficiency and Alternative Energy Technology Branch, EMR Canada 580 Booth Street, Ottawa K1A 0E4.

Energy, Mines and Resources Canada/CANMET



Bioenergy Fact Sheet

STUDIES SERIES

Bioenergy R & D Program Summary

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Study Objectives

The objective of this study was to contact researchers who received funds from the Energy, Mines and Resources Canada, Bioenergy Development Program from 1984 to 1986 and to gather information on the progress of the funded research. A second objective was the preparation of a summary report of the study results to date in digest form. The Biomass Energy Institute was the proponent for this study.

START DATE:	11/85
COMPLETION DATE:	12/87
APPLICABILITY:	
Industrial sector	Agricultural sector
Commercial sector	Institutional sector
Residential	
TYPE OF BIOMASS:	
Not specific to a type of biomass	
TYPE OF TECHNOLOGY:	
Not specific to a technology	
TOTAL STUDY COST:	\$44,563 (actual)

Background and Method

The National Research Council (NRC) maintained a database of projects funded by the Council prior to 1984. The Biomass Energy Institute acquired the NRC database, and added new projects funded under the Bioenergy Development Program of Energy, Mines and Resources Canada (EMR).

A format similar to the NRC summary was used to continue the data collection. A French translation of the file was completed. A camera-ready copy of the summary was to be supplied to EMR.

Bioenergy R & D Program Summary

(continued)

Results

The National Research Council Bioenergy Database was received, and Bioenergy Development Program information was obtained from scientific authorities. A questionnaire was sent to the principal investigators, and follow-up phone calls were made when questionnaires were not returned. Information received on the status of projects to April, 1986 was included in a suitable camera-ready format. There were 161 projects listed. Project descriptions were translated.

Many of the questionnaires were not completed and researchers were difficult to contact. It is recommended that status sheets, including summaries of results to date, be required when researchers submit invoices for payment, and should constitute part of the contract.

Publications

(1) BIOENERGY RESEARCH AND DEVELOPMENT: SUMMARY OF 1985, Bioenergy Development Program project no. 5-7148, Energy, Mines and Resources Canada, 1987.

Sources of outside financial support for this study included:

Source: EMR
Program: BDP
Proj. No: 5-7148
Value: \$44,563

Scientific Authority: E.N. Hogan

Funding for R&D supported by the Bioenergy Development Program (BDP) was provided by the Interdepartmental Panel on Energy R&D (PERD).

This fact sheet is one of a series. The information has been carefully checked and has been verified at source. The information presented was current as of:

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All fact sheets in this series are prepared using a computerized database, the Bioenergy Information and Technology Transfer System (BITTS).

For further information, contact the Efficiency and Alternative Energy Technology Branch, EMR Canada 500 Booth Street, Ottawa K1A 0E4.

Energy, Mines and Resources Canada/CANMET



Bioenergy Fact Sheet

STUDIES SERIES

Achievements in Bioenergy R&D

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Fax:

Study Objectives

The objective of this study was to research and prepare a publication on the Bioenergy Development Program. The publication provides an in-depth look at the program, its goals and accomplishments, an assessment of the present state-of-the-art of bioenergy technologies, how the priorities and objectives of the program relate to this situation, and a list of research studies. The report is in camera-ready copy in both official languages. Passmore Associates International was the proponent for this project.

START DATE: 07/85

COMPLETION DATE: 09/87

APPLICABILITY:

Industrial sector	Agricultural sector
Commercial sector	Institutional sector
Residential	

TYPE OF BIOMASS:

Not specific to a type of biomass

TYPE OF TECHNOLOGY:

Not specific to a technology

TOTAL STUDY COST:	\$43,039 (actual)
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Background and Method

Passmore Associates International, together with Ensyn Engineering Inc., reviewed Canadian accomplishments in the bioenergy field, assessing both the status and potential of various technologies and various biomass resources.

Achievements in Bioenergy R&D

(continued)

Results

AN OVERVIEW OF ACHIEVEMENTS IN BIOENERGY RESEARCH, DEVELOPMENT AND DEMONSTRATION was published in February, 1987. This publication reviewed Canadian accomplishments in bioenergy by assessing the status and potential of various technologies, such as materials preparation and handling, direct combustion, conversion to liquid fuels, conversion to gaseous fuels and conversion to chemical feedstocks. Each chapter concluded with a list of federal project references. A chapter was also devoted to environmental considerations. Various bioenergy-related development programs were discussed, and a summary was provided of the current state of biomass resources in Canada.

Publications

(1) AN OVERVIEW OF ACHIEVEMENTS IN BIOENERGY RESEARCH, DEVELOPMENT AND DEMONSTRATION, Bioenergy Development Program project no. 5-7014, Energy, Mines and Resources Canada, 1987.

Sources of outside financial support for this study included:

Source: EMR
Program: BDP
Proj. No: 5-7014
Value: \$43,039

Scientific Authority: E.N. Hogan

Funding for R&D supported by the Bioenergy Development Program (BDP) was provided by the Interdepartmental Panel on Energy R&D (PERD).

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06/07/90

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For further information, contact the Efficiency and Alternative Energy Technology Branch, EMR Canada, 580 Booth Street, Ottawa K1A 0E4.

Energy, Mines and Resources Canada/CANMET



Bioenergy Fact Sheet

STUDIES SERIES

Standard Methods for Biomass Analysis

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Study Objectives

This project is being carried out as a joint initiative by researchers in Canada, the United States, Finland, New Zealand and Italy, and has been sponsored in part by the International Energy Agency (IEA). The overall objective is to standardize international methods of biomass analysis in order to accelerate research and to improve its quality. A program developed by representatives of these countries performs three separate tasks: first, to carry out selected analysis comparisons between laboratories; second, to establish standard reference materials for biomass research; and last to assemble a sourcebook of relevant analytical methods and standards now in use within the industry.

START DATE:	02/87
COMPLETION DATE:	12/89
APPLICABILITY:	
Industrial sector	Agricultural sector
Commercial sector	Institutional sector
Residential	
TYPE OF BIOMASS:	
Not specific to a type of biomass	
TYPE OF TECHNOLOGY:	
Not specific to a technology	
TOTAL STUDY COST:	\$133,093 (estimated)

Background and Method

The past 15 years have seen an increase in the amount of biomass used in Canada and overseas, and analytical techniques and equipment have improved dramatically. The consensus has grown that standardization of biomass test methods and classification would enhance the results of all biomass research.

In 1986, as part of the IEA Bioenergy Agreement, a Voluntary Standards project was initiated by Canada, the United States, Finland, New Zealand, and Italy. Its aim is to identify, collect, evaluate, test and publish analytical methods of value to the biomass conversion and production communities.

Much of this work will be carried out at the Solar Energy Research Institute (SERI) in Colorado, and involves the establishment of a working group formed from representatives of all member countries which defines specific goals and tasks and oversees program administration.

A major part of this project is the publishing of a "Sourcebook of Methods of Analysis for Biomass and Biomass-Derived Fuels and Chemicals". This sourcebook presents titles and abstracts of test methods relevant to all aspects of biomass conversion. It has been assembled by an international team following a comprehensive literature search, together with a review of industrial standards and input of field scientists. The proceedings of national and international conferences have also been reviewed for contributory information.

Standard Methods for Biomass Analysis

(continued)

Results

Selective analysis comparisons between various international laboratories have initially focused on three representative experiments:

the hydrolysis of Sigmacell 50, the moisture content determination and analysis of a pyrolysis oil and a liquefaction oil, and the analysis of woody and herbaceous feedstocks. Experiments in each of these areas is being coordinated by a senior researcher who will analyse results from the various laboratories and attempt to define a universal test procedure. Fifteen laboratories from the U.S., Canada, Finland, New Zealand and Italy are participating in a research program that is expected to continue through to 1991. The biomass test sourcebook was published by SERI in early 1989, and lists titles and descriptions of biomass-related tests and standards. Areas of concentration include Preparation of Feedstocks, Physical and Thermal Properties, Elemental Analysis (e.g. oxygen content), Chemical Component and Group Analysis, Fuel Product Analysis, Waste Product Analysis, Conversion System Performance and Safety.

In addition to this work, Finnish researchers have produced a report detailing methods for testing the efficiency of small scale biomass combustors. Four research materials have now been received by the National Institute of Standards and Technology (formerly the National Bureau of Standards), Office of Standard Reference Materials, which is cost-sharing their preparation, packaging and distribution. The materials are <Pinus radiata> (without bark) from New Zealand; <Populus deltoides> (with bark) from southeast United States; wheat straw from Colorado; and sugar cane bagasse from Hawaii.

Publications

(1) T.A. Milne, Voluntary Standards for Fuels and Chemicals, BIOMASS, final report to the IEA 1986-1988.

(2) J.L. Walsh Jr. and T.A. Milne, ASTM STANDARDIZATION NEWS, Development of Standards for Biomass, 1989.

(3) T.A. Milne and H.L. Chum, SEVENTH CANADIAN BIOENERGY R&D SEMINAR, Methods of Analysis of Biomass for Fuels and Chemicals, Solar Energy Research Institute, 1989, pp. 737.

(4) T.A. Milne, SOURCEBOOK OF METHODS OF ANALYSIS FOR BIOMASS AND BIOMASS-DERIVED FUELS AND CHEMICALS, Bioenergy Development Program project no. 6-6183, Energy, Mines and Resources Canada, 1989.

Sources of outside financial support for this study included:

Source: EMR
Program: BDP
Proj. No: 6-6183
Value: \$133,093

Scientific Authority: E.N. Hogan

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For further information, contact the Efficiency and Alternative Energy Technology Branch, EMR Canada 380 Booth Street, Ottawa K1A 0E4.

Energy, Mines and Resources Canada/CANMET



Bioenergy Fact Sheet

STUDIES SERIES

CANPAC 1988

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Study Objectives

The objective of this study was the organization of the Canadian Power Alcohol Conference (CANPAC) for 1988. The Biomass Energy Institute of Winnipeg was the proponent for this study.

START DATE:	09/88
COMPLETION DATE:	03/89
APPLICABILITY:	Industrial sector
TYPE OF BIOMASS:	Not specific to a type of biomass
TYPE OF TECHNOLOGY:	Fermentation
TOTAL STUDY COST:	\$19,168 (actual)

Background and Method

Two Canadian Power Alcohol Conferences (CANPAC) were organized by the Biomass Energy Institute in the early 1980s. Enough new research, information, and experience had been gained since that time to provide opportunity for a third conference, CANPAC 88.

Results

The CANPAC 88, Alcohol Fuels for Transportation Conference was held in Winnipeg, Manitoba, on October 2 to 4, 1988, at the International Inn. The Canadian Renewable Fuels Association assisted in organizing the event. There were 90 people in attendance. Conference proceedings were published in December, 1988.

The two-day conference included sessions on federal and provincial policy, three technical sessions and a session on perspectives for the industry.

Publications

(1) Alcohol Fuels for Transportation, PROCEEDINGS CANPAC 88, Biomass Energy Institute, 1988, pp 252.

Sources of outside financial support for this study included:

Source: EMR
Program: BDP
Proj. No: 8-6090
Value: \$19,168

Scientific Authority: Dr. W.E. Lowe

Funding for R&D supported by the Bioenergy Development Program (BDP) was provided by the Interdepartmental Panel on Energy R&D (PERD).

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For further information, contact the Efficiency and Alternative Energy Technology Branch, EMR Canada 580 Booth Street, Ottawa K1A 0E4.

Energy, Mines and Resources Canada/CANMET

COMBUSTION

COMBUSTION: AN OVERVIEW

TECHNOLOGY DESCRIPTION

The direct combustion of biomass for the generation of thermal and electrical energy has the largest share of the traditional bioenergy market. Systems with operating records of 40 years or more have been retained through the era of low-cost petro fuels, and the technology has recently expanded into a variety of new applications. Although the basic concepts are similar, major differences in equipment configuration and operating procedures have evolved three distinct size categories: large, medium and small.

Large-Scale Systems (Greater than 40 GJ/h)

The largest source of bioenergy in Canada is derived from the recovery boilers of the pulp and paper industry. These field-erected, multi-storey units burn spent liquor containing dissolved lignin from wood to recover pulping chemicals and generate high-pressure steam for electrical and thermal energy for the mill. They provide over one-third of the total primary energy demand of the pulp and paper industry.

Hog fuel power boilers in the pulp and paper mills and large forest products industries also generate significant bioenergy. These integral combustor-boiler units burn hog fuel, a mixture of bark, sawdust, chips, clarifier sludges and other wood-derived mill residues. Minimal fuel preparation is required. Feedstocks are hogged to a maximum diameter of about eight centimetres and are usually mechanically dewatered to about 55 to 60 per cent moisture content. They are then burned in a thin bed on a mechanical grate.

Another large-scale conventional technology is the mass burning of municipal solid waste. While the primary objective is to reduce disposal requirements, energy is a significant product of many installations. These large-scale units, capable of handling several hundred tonnes per day, are well established in Europe and the U.S., and several systems are operating or under construction in Canada.

Large biomass-fired boilers are also used to generate electricity. Using purchased mill residues or whole tree chips as fuel, these facilities generate grid or local electricity, sometimes with associated supply of thermal energy as industrial process steam or hot water for district heating. To date, three facilities are or will soon be operating in Canada.

Medium-Scale Systems (10-40 GJ/h)

Conventional biofuel combustors are used extensively in the forest products industries. Systems are found in sawmills, veneer plants, furniture factories, composite product mills and throughout the secondary wood industries. These systems typically use site-generated biomass residues or wastes that, in many cases, would otherwise represent a disposal cost burden. Energy output in the form of low- to medium-pressure steam, hot oil or hot water, or as a hot gas flow is principally for thermal loads. Applications include lumber drying, log pond and veneer vat heating, flake and particle drying, veneer drying, hot press heating and space heating for buildings.

The specific technology and equipment varies widely depending on the fuel available and the form of energy required. Systems range from simple Dutch ovens and skid-mounted boilers operating on coarse fuels, to package boilers and single chamber combustors using hogged fuel or chips, to suspension burners operating on dry powder fuels. A combustion system is commercially available for virtually all fuel-energy combinations.

This same basic technology has been expanded to wood-fuelled systems for non-forest related installations. Operated on purchased wood residues or whole tree fuel chips, applications include hospitals, schools, universities, institutions and government building complexes. This technology is also found in smaller industrial applications, such as brick factories, greenhouses, foundries, and commercial facilities such as offices and shopping centres.

Small-Scale Systems (Less than 10 GJ/H)

By far, the greatest number of combustion systems are stoves and furnaces which usually burn solid chunk firewood for space heat for homes, garages, motels, farm buildings and stores. The traditional cookstove and boxstove have been replaced by controlled draft units, some with catalytic converters. Natural draft furnaces have been replaced by automatically regulated, high-efficiency furnaces and hot water boilers operating on solid firewood, or by particulate-fuelled systems with fully automated fuel-feeding -- and even self-ignition.

HISTORICAL PERSPECTIVE

Until very recently, the history of bioenergy has been based on the evolution of direct combustion, primarily of wood-based fuels. Early settlements used wood fuels for domestic space heating, cooking and water heating, with minor amounts of industrial shaft power supplied by water wheels. With the coming of the steam era, many early industries installed wood-fired Dutch ovens and horizontal return tubular boilers to provide process energy, and even shaft power with large stationary steam engines. Although first coal, and then oil and natural gas, replaced wood in most systems, many forest-related industries continued to derive a large portion of their energy supply from combusting in-plant-generated wood residues. In 1929, the first Canadian Kraft liquor recovery boiler was installed by Backcock & Willcox at Windsor Mills, Quebec, triggering the start of a biofuel sector that today forms the major source of biomass-derived energy in Canada.

Despite a market share of roughly 50 per cent in 1900, the role of biomass combustion had dropped to only about 3 per cent by the early 1970s. However, abrupt increases in world oil prices in the late 70s precipitated a decade of intensive alternative energy development. One of the greatest activities involved a rapid increase in the number of industrially proven direct combustion systems in the forest-related industries, as well as introduction of Scandinavian controlled-draft stoves in the residential sector. With today's comparatively low fossil fuel prices, biofuel use has stabilized. However, decreases in bioenergy use in the residential and industrial sectors are balanced by the steady introduction of wood combustion technology into the institutional and commercial sectors, particularly in the Atlantic region where natural gas is not indigenous and electricity costs are high.

CANADIAN ACHIEVEMENTS

The very large hog fuel powered boilers of the pulp and paper industry are one of the major Canadian applications of bioenergy. In times of low oil prices, these units often functioned as incinerators to dispose mill residues. With escalating oil prices and increased environmental concerns, greater emphasis was put on efforts to improve boiler performance in order to maximize energy production while minimizing undesirable emissions. A major boiler test program was initiated and co-ordinated by the Canadian Boiler Government with support from the Canadian Boiler Society, the American Boiler Manufacturers Association and the U.S. Environmental Protection Agency. Testing was carried out by a group of Canadian consulting firms under the direction of CANMET's Combustion and Carbonization Research Laboratory (CCRL).

A protocol was established for the test procedures, instrumentation and analyses required for on-site performance monitoring of hog fuel boilers. Test criteria included fuel characteristics, furnace temperatures and pressures, flue gas composition, emissions and ash characteristics, and calculation of excess air levels, mass and energy balances, and efficiency. A total of four hog-fuel boilers were tested, including travelling grate, gently sloping pinhole grate and steeply-inclined grate configurations.

Positive results from these tests include the following:

- direct reduction in oil-firing through performance optimization of the test boilers (with savings of over \$1 million per year for one test boiler);
- provision of baseline performance data for manufacturers to develop improved boiler designs, more effective instrumentation and boiler control strategies;
- establishment of emission characteristics for use by environmental protection agencies in development standards, and for use by equipment suppliers in optimization of pollution abatement technologies.

Following the lead established by the successful boiler test program, Environment Canada, in association with EMR and provincial environment ministries, set up a program of exhaustive on-site testing of municipal solid waste (MSW) incinerator emissions in relation to operating performance. Dioxins, furans, chlorobenzenes, chlorophenols, polychlorinated biphenyls, Polyaromatic Hydrocarbons (PAHs), particulates, heavy metals, acid gases and combustion gases have been measured in three applications: a two-stage modular boiler with waste heat recovery in P.E.I., a modified Von-Roll mass-burn unit in Quebec, and a refuse derived fuel (RDF) fired suspension system in Connecticut in the U.S. Data from these tests are being used to optimize performance of existing facilities, to develop new incinerator designs and improved pollution abatement equipment, and to establish emission standards.

Sandwell Swan Wooster Inc. of Vancouver has examined the fundamental principles involved in achieving effective air injection into Kraft recovery boilers and hog-fuel-fired power boilers. Design concepts and a general computer program have been developed to allow optimal mixing of combustion air with fuel volatiles. Successful application of these concepts should reduce fossil fuel use, improve thermal efficiency, decrease particulate and hydrocarbon emissions, and provide improved load following capability.

To provide a dedicated system for research and development on biomass combustion, a state-of-the-art test facility was set up at ORTECH International in Mississauga, Ontario. A KMW Energy 300 reciprocating grate combustor and fire-tube hot water boiler were installed and fitted with a sophisticated computerized monitoring system which measures 35 operating parameters. Test programs on combustion of pine cones and rice hulls and characterization tests on five Canadian biomass fuels have been undertaken.

A residential bioenergy program has been conducted to make household heating with biofuels more efficient and economical, safer, cleaner and more convenient. Initial work at Canadian Combustion Research Laboratory (CCRL) on domestic wood burning stoves established a test protocol for measurement of emissions and efficiency. Extensive performance monitoring of roundwood-fired central heating systems and Scandinavian chip-fired stoker units followed. Supported by these results, research and development projects focused on combustor design improvements and equipment modifications to improve efficiency and reduce emissions. This work culminated with the establishment of three high-efficiency, low-emission designs for chip-fired heating systems, one of which is now being produced commercially in P.E.I. with 90 per cent Canadian-made components. Efficiency has been raised from just over half to almost 80 per cent, and particulate emissions have been reduced by over 95 per cent.

The Canadian Standards Association, with support from EMR's Bioenergy Development Program through participation by CCRL, Environment Canada and the appliance manufacturers through the Canadian Wood Energy Institute, developed and established standards for solid fuel household heating appliances. These standards cover design, performance testing, certification, installation and operation. In addition, a detailed Safety Training Manual was produced for installers, inspectors and maintenance personnel.

The Canadian pulp and paper industry produces several thousand tonnes of sludge per day from their waste water treatment facilities. Just over half is incinerated, often with little or no net energy recovery, and the rest is landfilled. The N.B. Research and Productivity Council is examining the potential of sludge as fuel in circulating fluidized-bed combustors. Fresh and aged sludges from a local pulp company are being combusted separately and in combination with coal and shale fuels in a pilot-scale combustor. Emissions, combustion characteristics, mass/energy balances and ash quality are being carefully monitored.

INTERNATIONAL PERSPECTIVE

The combustion of biomass is a significant energy source on the global scale. While many Third World countries generate a large portion of their primary energy from biofuels, the majority of applications are simple, conventional small fires for heating and cooking. On the other hand, many industrialized nations, particularly the U.S. and countries in Western Europe, have moved rapidly ahead with substantial bioenergy development and implementation programs. Depleting fossil fuel resources, pressure for new waste disposal methods and strong government commitments to the benefits of indigenous, renewable energy use have resulted in large-scale use of biofuels.

In the U.S., there are now over 25 biofuel-based electrical utility generating stations in operation or under construction, not including plants operating on municipal solid wastes (MSW). They utilize whole tree chips, demolition/urban wood wastes, manure, nut shells and fruit pits, orchard and vineyard prunings, forest industry residues or any other available combustible biofuel.

In Denmark, the fuel energy tax structure (25 per cent on wood chips and 150 per cent on heavy oil), permits a lower net cost for bioenergy (about 20 per cent). As a result, more than 30 district heating plants, many with co-generation of electricity, are now operating fueled by biomass. Straw is used extensively, fuelling over 15,000 small farm-scale combustion systems and about 20 per cent of Denmark's district heating plants.

In Sweden and Finland, large-scale direct combustion of biofuels is also well established. Systems are fuelled with forest industry residues, whole tree chips, milled and sod peat, densified biomass fuel pellets and MSW. The production, marketing and use of dry pulverized wood has been implemented for pulp mill lime kilns and for central district heating plants. Energy-from-waste plants utilize over 70 per cent of MSW in Sweden, and about 30 refuse-derived fuel or mass incineration systems are in operation.

CURRENT ACTIVITIES

The EMR program in direct biofuel combustion emphasizes cost-effective systems that achieve high efficiency with minimal emissions. The following are identified as R&D priorities:

- improvement in general combustor performance, particularly in small-to-medium scale systems, emphasizing greater cost-effectiveness, improved overall efficiency, reduced air emissions, and better control systems;
- increased market penetration by adaptation to a wider range of feedstocks, strongly emphasizing the use of waste materials that pose a significant disposal problem;
- assurance that existing technologies can meet more stringent emission regulations and that input data are developed to establish a sound scientific basis for new emission regulations;
- support for new combustion processes, such as pulverized fuel burners and fluidized-bed combustors;
- standards development and emissions reduction for residential systems.

The combustion of sludges and coke are specific on-going projects that address these objectives. Tests underway at the New Brunswick Research and Productivity Council (RPC) are providing information on the circulating fluidized-bed combustion of fresh and aged clarifier sludges obtained from a N.B. pulp mill. Tests include burning the sludges separately and in combination with supplementary conventional fuels, such as coal. These tests at RPC are being conducted as a forerunner for further trials of wood waste and clarifier sludge in combination with coal in New Brunswick Power's 30 MW circulating fluidized bed unit at Chatham N.B. UNIGEC, in collaboration with the University of Quebec at Chicoutimi, is testing a circulating fluidized-bed system with coke dust made surplus from carbon anodes required in the aluminum industry.

ORTECH International, with support from EMR, is working toward improvement in operating efficiency and increased cost-effectiveness of small-to-medium-scale commercial, industrial and institutional biofuel combustion systems. Field monitoring data from commercial installations are being correlated with data collected from the burning of common fuels in the highly instrumented ORTECH laboratory combustion test facility. This information will be used to develop appropriate control technology that will ensure the most efficient and minimal-emission operation of future combustion systems.

A small stationary bed wood-chip combustion system has been installed at CCRL to complement CANMET's existing bubbling-bed and circulating fluidized-bed combustion test units. Combustion emissions are also being studied by MONENCO through development of detailed cost assessments of various air pollution control systems for biofuel combustion systems.

EMR is continuing work on residential wood-chip and roundwood furnaces and, in cooperation with the Canadian Standards Association (CSA), the development of standards for design, manufacture, testing, installation, operation and safety. Efforts to minimize system weight and production costs, to improve fuel loading and ash handling, and to restrict air emissions are on going.

Parrsboro Metal Fabricators have evaluated and redesigned the Alternative Energy Systems (AES) wood-chip-fired hot air furnace. A test unit built to CSA certification standards will be extensively evaluated at the Institut de recherche en technologie appropriée (IRTA) test facility and in field applications. A program being conducted by Ryerson Polytechnical Institute will design, fabricate and test a 12-hour burn, roundwood fired, catalytic furnace. This system will also be extensively tested at IRTA.

FUTURE DIRECTIONS

The EMR program will emphasize on going improvement in biofuel combustor performance in order to achieve greater cost-effectiveness, reduce adverse environmental impacts, and promote bioenergy use through adaptation of direct combustion technologies to a wider range of biofuels. Specific attention will focus on development and implementation of systems to effectively utilize waste materials that represent significant disposal problems.

Continuing efforts will address the co-operative development of standards for manufacture, installation, testing, operation and maintenance of biomass-fueled appliances.

R&D PROJECT SUMMARIES

Combustion



COMBUSTION

- Grate System
- Fluidized Bed
- Suspension
- Other



Bioenergy Fact Sheet

STUDIES SERIES

Wood Furnace/Boiler Cycling Performance

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Study Objectives

The primary objective of the study was to determine the cyclic operation patterns of combination wood/oil and wood/electric furnaces and boilers installed in houses located in the Atlantic Provinces. This information assisted in revisions to CSA B-415 to allow it to accommodate central heating systems. At the time of this project the standard accommodated stand-alone wood stoves only. Adsett & Associates Ltd. were the proponents for this study.

START DATE:	12/85
COMPLETION DATE:	01/87
APPLICABILITY:	
Industrial sector	Residential
TYPE OF BIOMASS:	
Forest crop for bioenergy	Forest waste/waste timber
Mill or factory waste	
TYPE OF TECHNOLOGY:	
Combustion (grate system)	
TOTAL STUDY COST:	\$60,000 (actual)

Background and Method

Data generated by the study were measured and stored on magnetic cassette tapes by means of automatic data gathering equipment. The equipment allowed a maximum input of 16 digital and 18 analogue per module. For this project one module was required per site. The temperatures and cyclic information were read each minute, totalled and recorded on tape each hour, and then reset. Each cassette was capable of holding one week of data. The only functions required by the home owner during the study were the weighing and recording of wood fuel, the changing of a cassette tape within the module each week, and the mailing of the recorded tape to Adsett & Associates Ltd. The information on the recorded tapes were processed in order to provide weekly data tables. For each of the two locations the following units were monitored: two wood/oil combination hot air furnaces; one oil/wood add-on air furnace; one wood/electric hot air furnace; and two wood/oil hot water boilers.

Monitoring included such things as weight of daily wood, oil, and electricity consumption; indoor house temperature; outdoor air temperature; total on time; and the number of on/off cycles. The total program was divided into the following tasks: test unit determination which involved the selection of the units to be used in the study; monitoring equipment and computer model modifications which involved determining which actual data were required by the client; ongoing monitoring which included the receiving and processing of all data, ensuring that equipment was operating correctly, making necessary corrections to the operation of equipment, and performing wood and moisture tests; data reduction which included additional software modifications required to provide tables and graphs as well as performing the analysis and providing the client with the required information; and the generation of reports which dealt with the production of weekly data indicating ongoing performance of the units.

Wood Furnace/Boiler Cycling Performance

(continued)

Results

Six systems located in homes in Fredericton, N.B. and six systems located in Moncton, N.B. were monitored by means of automatic data gathering and reduction. In order to perform this work, 12 data acquisition units were purchased for location on-site. Data collected included the analogue input of the temperatures for internal space, ambient outdoors and the heat transfer medium, as well as the digital input concerning cycling operation of the dampers, blowers/pumps, high-temperature limit switches, and oil burners.

The data obtained on-site were transferred to cassette tapes. The cassettes were sent to Adsett & Associates where the data were reduced to tabular and graphic form. The resultant graphs are shown in the appendices of the final report.

Publications

(1) MONITORING OF WOOD FURNACE/BOILER CYCLING PERFORMANCE, Bioenergy Development Program project no. 5-7254, Energy, Mines and Resources Canada, 1986.

Sources of outside financial support for this study included:

Source: EMR
Program: BDP
Proj. No: 5-7254
Value: \$60,000

Scientific Authority: I.B. Flann

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For further information, contact the Efficiency and Alternative Energy Technology Branch, EMR Canada, 880 Booth Street, Ottawa, K1A 0E4.

Energy, Mines and Resources Canada/CANMET



Bioenergy Fact Sheet

STUDIES SERIES

Emissions Testing of Four Appliances

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Study Objectives

The main objective of this work was to measure and report on emission levels (grams of pollutant per kilogram of fuel used, grams of pollutant per cubic metre of flue gas generated, and grams of pollutant per hour) for a number of particulate wood burning appliances located within New Brunswick. The emissions monitored were to include the following: CO, CO₂, O₂, SO₂, NO_x, HC. Adsett & Associates Ltd. was the proponent for this project, with the New Brunswick Research and Productivity Council acting as a subcontractor.

START DATE:	03/85
COMPLETION DATE:	07/85
APPLICABILITY:	
Industrial sector	Residential
TYPE OF BIOMASS:	
Forest crop for bioenergy	Forest waste/waste timber
Mill or factory waste	Animal waste, manure
TYPE OF TECHNOLOGY:	
Combustion (grate system)	Fixed bed gasification
TOTAL STUDY COST:	\$37,152 (actual)

Background and Method

The four heating appliances tested in this study were a Saasmo Model H80-83 gravity-fed wood chip gasifier coupled to an Olsen hot-air furnace provided with oil fired back up; an Anga Varne biomass-fired boiler system with a New Yorker oil-fired boiler present as backup; and the Skogma 077 burner and a Heat Harvester TB 500 burner, coupled in turn to a CTC boiler unit. In all, 24 tests were performed representing a wide variety of fuel types, moisture contents, and feed rates. Each test comprised three phases: High Volume Sampling, which consisted of suspending a sheet metal cone 1.1 m in diameter on a frame over the chimney top. A section of 10-cm flexible aluminum duct was then connected to an assembly consisting of a pair of high capacity blowers and a filter holder. The blower drew roughly 38 l/sec. of air through a 25.4 cm x 20.3 cm, 0.3 micron glass fiber filter. The pre-weighed filter collected the particulate matter for a period of 15 minutes through the burn. Filters were then sent to the laboratory for analysis.

The EPA 5/7 Method (Oregon Procedure) dealt with the isokinetic removal of particulate matter from the stack and the determination of its weight after the removal of water. The combustion gas monitoring consisted of continuous analysis during the length of each test run. Outputs from the analyzers were fed to a 48-channel programmable Kaye Digistrip III datalogger which produced printouts of the information as well as transferring it to computer for storage on magnetic tape. Stack gas temperature was determined using an array of 5 type-K thermocouples mounted at various locations in the stack and wired into the datalogger.

The five inputs were averaged by the device.

Emissions Testing of Four Appliances

(continued)

Results

In a number of tests, specifically Short 8-14, high levels of excess oxygen were encountered. It is thought that this was a function of stoker operation rather than any difficulty with the gas analysis. It was observed that certain fuels (softwood sawdust, mixed softwood chips and bark) did not feed at a constant rate much of the time. Because of this rat holing effect the screw would tend to temporarily run dry, creating a situation of fuel starvation and thereby leading to high oxygen levels. It was observed that in roughly half of the tests the initial 3 or 4 SO₂ readings were very high, after which they tapered off quickly to an expected range of 0-15 ppm. It appeared likely that the calibration gases, used prior to each test, were not entirely purged from the sample line and/or the analyzer. After some use the system cleared itself and the readings stabilized. Generally speaking, the particulate fuels with the lowest moisture contents produced the highest efficiencies.

The group of eight fuels with moisture contents in the 9% - 13% range yielded an average efficiency of 68% while the group of seven fuels in the 40% moisture range produced an average efficiency of 48%. The particulate emission results obtained by the EPA method were consistently higher than those obtained by the high volume method. Although it is not possible to state which was the more accurate, it should be noted that the latter technique is difficult to implement in the field and is susceptible to prevailing weather conditions. This indicates, in all probability, that the EPA method was more suitable to the task at hand. Particulate emission levels were quite dependant on fuel type and moisture content. Sawdust produced higher emissions than chips, while dry chips generally performed better than wet chips.

Publications

(1) EMISSIONS TESTING OF FOUR WOOD PARTICULATE-FIRED APPLIANCES IN THE FREDERICTON AREA, Bioenergy Development Program project no. 4-6204, Energy, Mines and Resources Canada, 1985.

Sources of outside financial support for this study included:

Source: EMR
Program: BDP
Proj. No: 4-6204
Value: \$37,152

Scientific Authority: I.B. Flann, J.M. Charron

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Energy, Mines and Resources Canada/CANMET



Bioenergy Fact Sheet

STUDIES SERIES

Catalogue of Small-Scale Combustors

Principal Investigator

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Study Objectives

This project updated a 1980 EMR publication entitled "A Catalogue of Wood/Energy Conversion Systems - Small Scale Combustion and Retrofit Gasifiers". The study provided small industries, institutions and commercial establishments with a comprehensive technical guide to small-scale combustors currently marketed in Canada. The guide serves as a reference for specific technologies or as a tool for initial screening of available equipment. An index is included which assists the user in selecting the type of combustor most suitable to the available fuel. B.H. Levelton & Associates Ltd. was the proponent for this project.

START DATE:	03/87
COMPLETION DATE:	02/89
APPLICABILITY:	
Industrial sector	Commercial sector
Institutional sector	
TYPE OF BIOMASS:	
Forest crop for bioenergy	Municipal solid waste
Forest waste/waste timber	Mill or factory waste
TYPE OF TECHNOLOGY:	
Combustion (grate system)	Fluidized bed combustion
Combustion (suspension)	
TOTAL STUDY COST:	\$66,497 (actual)

Background and Method

Information used in the catalogue has been drawn from a number of sources. The point of departure for this study was the 1980 report prepared by the Wood Energy Group of Forintek Canada Corp., which listed more than 80 commercial systems operating on wood-based fuels.

This study has a broader focus, identifying all manufacturers and suppliers of combustors which use any type of biomass fuel to provide thermal outputs in the 0.2 to 21.1 GJ/h range.

The work plan covers a comprehensive review of existing literature, followed by the development of a mailing questionnaire which is sent to all Canadian manufacturers and suppliers of biomass combustion equipment.

Returned questionnaires are processed, and technical data and equipment specifications are entered into a database. The catalogue includes both a description of current biomass combustion technologies and a compilation of manufacturers and their equipment, including system specifications and costs, ancillary equipment requirements, and the names and locations of existing installations. The equipment listings include descriptions of single and multiple chamber combustors, fluid-bed combustors, suspension burners and integral systems (i.e. "boilers").

Catalogue of Small-Scale Combustors

(continued)

Results

The catalogue presents the user with a complete list of suppliers of combustors in Canada suitable for use with a wide variety of biomass fuels. The information is organized in a standard format to facilitate use of the report. The entries for each supplier of equipment include information on system design, capacities of available models, costs, ancillary equipment requirements and a partial list of recent installations. A list of consultants, organized by province, is also included in the catalogue.

Publications

(1) A CATALOGUE OF SMALL SCALE COMBUSTORS FOR BIOMASS FUELS, Bioenergy Development Program project no. 6-6287, Energy, Mines and Resources Canada, 1988.

Sources of outside financial support for this study included:

Source: EMR
Program: BDP
Proj. No: 6-6287
Value: \$66,497

Scientific Authority: J.E. Robert

Funding for R&D supported by the Bioenergy Development Program (BDP) was provided by the Interdepartmental Panel on Energy R&D (PERD).

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For further information, contact the Efficiency and Alternative Energy Technology Branch, EMR Canada 500 Booth Street, Ottawa K1A 0E4.

Energy, Mines and Resources Canada/CANMET



Bioenergy Fact Sheet

STUDIES SERIES

Evaluation of Hot Gas Recirculating System

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Study Objectives

The objective of the Centre de Recherche Industrielle du Québec's (CRIQ) initial study (#6-6083) was to determine if "flue gas recirculation" (as used with other fuels) could significantly improve completeness of combustion in wood fired appliances. The follow-up project #8-6133 has two main objectives. The first is to show that the recirculation of hot gases makes it possible to significantly improve the performance of a wood furnace in two ways: by increasing efficiency and by decreasing polluting emissions. The second objective is to demonstrate that it is possible to design a mechanical recirculation system which is durable and can operate reliably on a furnace subjected to normal use, without the cost of the system being prohibitive.

START DATE: 07/86

COMPLETION DATE: 09/89

APPLICABILITY:

Residential

TYPE OF BIOMASS:

Forest crop for bioenergy

Forest waste/waste timber

Mill or factory waste

TYPE OF TECHNOLOGY:

Combustion(grate system)

TOTAL STUDY COST:

\$108,543

(actual)

Background and Method

It is clear that to obtain the level of comfort provided by a gas, oil or electric system, wood must be used in a central system. The previous project, Development, Testing and Evaluation of Flue Gas Recirculation Systems for Warm Air Furnaces (#6-6083), demonstrated that drawing gases from the chimney into the combustion area tends to improve the performance of a wood furnace. However, the fact that gases leaving the heat exchanger were used caused some difficulties. Since the gases had already been cooled, condensation tended to form on the fan, quickly clogging the system and reducing its reliability. The experimental systems will be installed on a Newmac warm air furnace, Model WB-100E. This furnace was initially chosen because, in the past, a variety of projects using this particular model were performed resulting in a substantial amount of data. The testing of three different configurations is proposed. Each performs the same task of drawing hot gases back into the combustion area before they enter the heat exchanger.

The performance of the furnace will be measured in accordance with the CSA B-415 provisional standard. These standard tests will provide the criteria for comparison of the systems: efficiency and total volume of emissions (CO and CH₄). Supplementary temperature measurements will be carried out on various mechanical components of the systems in order to determine certain design criteria such as the choice of materials and the position of the elements. Finally, the best performing system will undergo prolonged testing to assess its reliability. For each of the three configurations, tests will be carried out at three different rates of flow in order to find the optimum recirculation rate in each case. These tests will be carried out at both maximum and minimum combustion capacity. Following these tests, the best performing system will be tested at the optimum rate and at two intermediate capacities. The furnace equipped with the recirculation system will be operated in conditions simulating normal use. At the end of this period, a standard test at full and low capacity will be carried out in order to compare the system's performance before and after the endurance test. The results of the experiment will be analysed and a final report containing the results and recommendations will be written.

Evaluation of Hot Gas Recirculating System

(continued)

Results

The tests carried out for project #6-6083 have proven that it is possible to improve the performance of a wood furnace by drawing flue gases back into the combustion chamber. The results also demonstrated that in order to reduce pollution-causing emissions, even at low capacity, the gases must be drawn to the front of the chamber and the rate of recirculation must be at the optimum level for the particular furnace.

The optimum rate of recirculation for the best possible performance cannot currently be predicted for a given furnace. It can only be determined through further experimentation.

The final mechanical recirculation system cuts emissions in half at all burn-rates; however, emissions are still 3 to 6 times higher than the accepted standard for wood stoves.

Publications

(1) P.A. Larue, WARM AIR FURNACE CYCLING STUDY, C.R.I.Q. report no. FAB-85-078, 09/85.

(2) P.A. Larue and P. Renaud, ESSAI DE FOURNAISE - CCRL, C.R.I.Q. report no. FAB-85-099, 11/85.

(3) P.A. Larue and P. Renaud, SEVENTH CANADIAN BIOENERGY R&D SEMINAR, Developpement de Systeme de Recirculation des Gaz, C.R.I.Q., 1989, pp. 603.

Sources of outside financial support for this study included:

Source:	EMR	EMR
Program:	BDP	BDP
Proj. No:	6-6083	8-6133
Value:	\$45,151	\$63,392

Scientific Authority: I.B. Flann

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For further information, contact the Efficiency and Alternative Energy Technology Branch, ENR Canada 580 Booth Street, Ottawa K1A 0E4.

Energy, Mines and Resources Canada/CANMET



Bioenergy Fact Sheet

STUDIES SERIES

Develop Performance Data for Central Systems

Principal Investigator

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Study Objectives

The objectives of this study were to test a variety of solid fuel central heating systems in order to evaluate their performance and to establish benchmark data; to help develop a testing standard for the efficiency, emissions and power output of solid fuel central heating systems; and to provide new data for improvement of Canadian equipment. Institut de Recherche en Technologie Appropriée was the proponent for this study.

START DATE:	09/85
COMPLETION DATE:	04/86
APPLICABILITY:	
Industrial sector	Residential
TYPE OF BIOMASS:	
Forest crop for bioenergy	Forest waste/waste timber
Mill or factory waste	
TYPE OF TECHNOLOGY:	
Combustion(grate system)	
TOTAL STUDY COST:	\$64,687 (actual)

Background and Method

A review of existing literature reveals a need for standardized definitions in the area of solid fuel appliance evaluation. Manufacturers' statements are meaningless unless they are based on standardized procedures and definitions. Some literature quotes efficiency or combustion efficiency figures without stating the methodology used, to determine these numbers, while other material states the methodology used but gives misleading results.

The CSA B415 Standard working document (Appendix 11) was used to establish the basic methodology for this study, i.e. test facilities, instrumentation, fuel, general test procedures, and computational procedures. IRTA diverged from this document whenever the appliance did not fit within the established parameters. They also diverged from Article 6.1.1 by making manual adjustments to the combustion air controls to simulate thermostatic controls during the tests. Energex wood pellets and cattail pellets were used in the pellet furnaces and Douglas fir in the wood burning boilers. The computer algorithm to calculate results from pellet fuels was also modified.

Develop Performance Data for Central Systems

(continued)

Results

Efficiency levels were found to be below expectations, with few of the tested appliances achieving acceptable levels. Although efficiency is not a major requirement of many consumers, preoccupation with emissions is becoming increasingly important. Environmentalists want cleaner air and consumers want less creosote. Action by regulatory authorities would eliminate the offenders and put pressure on most manufacturers to improve their products. The same action will arouse public attention and might provide an incentive to exchange old appliances for new ones with enhanced efficiency and lower emissions.

The study provided the basis for a standardized testing procedure for wood furnaces. This procedure will aid manufacturers in the development of more efficient and cleaner appliances.

Publications

Final Report is confidential and not available for distribution.

Sources of outside financial support for this study included:

Source: EMR
Program: BDP
Proj. No: 4-6312
Value: \$64,687

Scientific Authority: I.B. Flann

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For further information, contact the Efficiency and Alternative Energy Technology Branch, EMR Canada 580 Booth Street, Ottawa K1A 0E4.

Energy, Mines and Resources Canada/CANMET



Bioenergy Fact Sheet

STUDIES SERIES

Effect of Firebox Modification on Boilers

Principal Investigator

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Study Objectives

The objective of this research was to improve the efficiency and reduce the emissions from a wood-burning furnace at low-heat output (15 to 30 MJ/h), through modifications to its combustion chamber. An evaluation of how catalytic combustors of different surface areas affect combustion characteristics was also conducted. The study was also to determine whether simplified testing procedures could be used by manufacturers to test the effectiveness of various appliance modifications.

This study led to a continuation study. Refer to BITTS #50310.

START DATE:	10/85
COMPLETION DATE:	07/86
APPLICABILITY:	
Industrial sector	Residential
TYPE OF BIOMASS:	
Forest crop for bioenergy	Forest waste/waste timber
Mill or factory waste	
TYPE OF TECHNOLOGY:	
Combustion (grate system)	
TOTAL STUDY COST:	\$48,821 (actual)

Background and Method

In a previous study for Energy, Mines and Resources Canada, IRTA tested the performance of 10 Canadian furnaces and boilers. The general performance levels were determined to be poor with potential for improvement with research and development. Manufacturers ensure the appliances comply with the appropriate safety standards, but little effort is made to improve efficiency and emission levels. A modified version of Canadian Standards Association (CSA) Preliminary Standard B415-M1986, Performance Testing of Solid Fuel Burning Appliances could be a useful development tool for manufacturers. A CSA-certified Surefire 801B domestic roundwood furnace, rated at 42 MJ/h, was tested using CSA B415. Testing was conducted on seven fire box configurations to determine the effects on performance with specific modifications. The appliance was first modified by placing a single row of firebricks on the sides and back of the combustion chamber, and insulating the bottom half of the loading door.

Next, a second row of firebricks was added to the sides and back of the combustion chamber, and the remainder of the loading door was insulated.

The third modification consisted of the addition of a row of firebricks on top of the combustion chamber. Testing was done to evaluate the appliance's performance with catalytic combustor blocks placed between the fire chamber and the heat exchanger. The first test was made with the firebrick-lined unit with one catalytic block, then with two and then three blocks. The two-catalytic block design was also tested without a combustion chamber liner and with a steel liner. To determine whether manufacturers could upgrade an appliance design by using dilution tunnel data alone, instead of conducting the entire B415 test, dilution tunnel data were compared with data from the full B415 procedure. Stack temperatures and any condensation caused by excessive heat exchange at low outputs were recorded throughout the combustion. The tests were conducted at a burn rate of 22 MJ/h, which is representative of average home operation.

Effect of Firebox Modification on Boilers

(continued)

Results

Using the CSA B415 testing standard it was demonstrated that, in the Surefire 801B, high heat transfer in the firebox is detrimental to proper combustion and that an insulated firebox performs better than an uninsulated firebox, with or without catalytic combustors.

Results of the appliance modifications showed that the firebrick liner provides a slight improvement in efficiency and a 24% reduction in particulate emissions over the original design. Catalytic combustors were found to provide a large reduction in emissions and increased efficiency up to the 80% range. The addition of a single block combustor resulted in a 53% reduction in particulate emissions.

It was determined from the test results that dilution tunnel data are satisfactory to evaluate modifications performed on the combustion chamber of the Surefire 801B.

The same conclusions were reached as to best design when using the complete B415 methodology. In the opinion of IRTA, a dilution tunnel can be used as an efficient development tool by manufacturers.

Publications

(1) C. LeMay, Performance Improvement of a Roundwood Furnace at Low Heat Output (15 TO 30 MJ/H) by Modification of the Combustion Chamber, SIXTH CANADIAN BIOENERGY R&D SEMINAR, 1987, pp. 513-516.

(2) C. LeMay, MONITORING AND TESTING OF THE ESHLAND MODEL E 100 WOOD BOILER, Bioenergy Development Program project no. 5-7135, Energy, Mines and Resources Canada, 1986.

Sources of outside financial support for this study included:

Source:	EMR	EMR
Program:	BDP	BDP
Proj. No:	4-6205	5-7135
Value:	\$25,000	\$23,821

Scientific Authority: I.B. Flann

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For further information, contact the Efficiency and Alternative Energy Technology Branch, EMR Canada 580 Booth Street, Ottawa K1A 0E4.

Energy, Mines and Resources Canada/CANMET



Bioenergy Fact Sheet

STUDIES SERIES

Retrofit of Stokers to Heat Exchangers

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Study Objectives

The first objective of this project was to determine whether a wood chip stoker can be tested and certified for subsequent retrofit coupling to a previously certified heat exchanger so that the "new" stoker-heat exchanger system is certifiable. The second objective was to determine the emission levels and energy transfer efficiency of certain retrofit combinations while operating with particulate fuels. The third objective was to explain the dynamics of various possible combinations of stokers and heat exchangers. The Institut de Recherche en Technologie Appropriée (IRTA) is responsible for this project.

START DATE:	08/87
COMPLETION DATE:	09/88
APPLICABILITY:	Residential
TYPE OF BIOMASS:	Forest crop for bioenergy Forest waste/waste timber Mill or factory waste
TYPE OF TECHNOLOGY:	Combustion(grate system)
TOTAL STUDY COST:	\$230,155 (actual)

Background and Method

Widespread conversion of residential heating from oil to wood in parts of Canada with abundant supplies of low-quality wood is almost certain to involve wood chips rather than conventional firewood. Also, it is likely to involve the retrofit of chip stokers and preheaters to existing (oil fired) heat exchangers rather than new heat exchangers (both furnaces and boilers). There are also likely to be many conversions because of increased convenience and efficiency. The current technical obstacles to such conversions relate to safety concerns and to lack of technical experience. The Canadian Standards Association (CSA) will not permit certification of retrofit installations because there is no experience to demonstrate that it can be done safely. Some stokers may be compatible with some heat exchangers, but not with others: two appliances may be physically compatible, but the flame impingement pattern of the stoker is not compatible with the heat exchanger, causing hot spots to develop with certain firing rates and fuel type combinations.

Also, the appliances may be compatible, but the combustion efficiency of the system may be unacceptably low. A preliminary approach based on safety and efficiency was developed for determining retrofit compatibility and fuel handling. High-fire temperature measurements, emission levels and heat transfer capacity results were also monitored. The approach was periodically modified as limitations involving each stoker/exchanger combination were discovered. A summary of test results and operating problems was recorded, resulting in the development of preliminary specifications/modifications that appear necessary to CSA Standard B-415 to accommodate chip-fired central systems.

Retrofit of Stokers to Heat Exchangers

(continued)

Results

Most stokers and pre-heaters tested gave good handling and combustion results with screened chips and pelletized fuels. No appliance produced good combustion results with fuels such as sawdust, chipper fines, and whole tree chips. Fuel delivery unreliability was one of the major problems with particulate fuel burners.

It is difficult to design a particulate fuel burner that will handle the many variations in size and moisture content of particulate fuels.

Arbitrary choice of a furnace or boiler for coupling to a stoker or pre-heater can create a mismatch, robbing the system of efficiency and increasing its emissions.

Restrictions should be placed on the installation of particulate fuel burners to ensure that they can be used safely and efficiently, and they should be certified to CSA B366.1 standards.

It is recommended that pelletized wood fuels be used in particulate fuel burners in areas where they are available at competitive prices.

Publications

(1) C. Lemay and G. O'Connor, SEVENTH CANADIAN BIOENERGY R&D SEMINAR, Establishment of Criteria for the Retrofit of Chip Stokers to Roundwood-Burning Furnaces and Boilers, I.R.T.A., 1989, pp. 613.

(2) C. Lemay and G. O'Connor, DESIGN AND PERFORMANCE OF WOOD-CHIP-FIRED STOKERS AND PRE-HEATERS (OUTPUT RANGE 25 TO 75 KW), Bioenergy Development Program project no. 7-6003, Energy, Mines and Resources Canada 1988.

Sources of outside financial support for this study included:

Source: EMR
Program: BDP
Proj. No: 7-6003
Value: \$230,155

Scientific Authority: I.B. Flann

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Energy, Mines and Resources Canada/CANMET



Bioenergy Fact Sheet

STUDIES SERIES

Monitoring of a TP 2000-30kW Stoker

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Study Objectives

The Institut de Recherche en Technologie Appropriée's (IRTA) project objective was to install and monitor a TP 2000-30kW woodchip stoker at the 140 square meter Glaude residence in Rockland, Ontario over the 1987/88 heating season.

START DATE: 09/86

COMPLETION DATE: 07/88

APPLICABILITY:

Commercial sector

Residential

TYPE OF BIOMASS:

Mill or factory waste

TYPE OF TECHNOLOGY:

Combustion(grate system)

TOTAL STUDY COST: \$35,994
(actual)

Background and Method

In 1986, IRTA was awarded a contract by EMR to install a Dan Trim particulate fuel burner at the Glaude residence in Rockland, and to monitor its operation over the 1986/87 heating season. The unit was not delivered by February, 1987, so the decision was made to install a TP 2000-44kW stoker in the residence in March. Although the 1987 monitoring period was short, the fuel burner provided information useful in determining requirements for the next winter's heating installation. The Dan Trim pre-heater was delivered in the spring of 1987, and a study in the fall revealed several operating problems with the unit. As a result, a TP 2000-30kW chip-fired stoker was installed and monitored for the 1987/88 heating season. The stoker consists of a 0.43 cubic metre storage bin, an auger feed mechanism and a cast steel combustor tube. The bottom-feeding, 10 cm auger pushes fuel through a tube to a cylindrical cast steel combustor tube.

A fan supplies combustion air through a series of small holes in the tube where combustion takes place. The stoker is connected to a Hunter 801B furnace that serves as a heat exchanger. The fuel used is green hardwood chips (moisture content is approximately 37%) purchased from a sawmill. To monitor the operation of the stoker over the heating season, an elapsed time meter and event counter were wired into the stoker's electrical circuit. The elapsed time meter recorded the amount of time the stoker operated, and the event counter totalled the number of times the stoker cycled on/off. The quantity of fuel chips used daily was monitored in two ways. First the stoker's feed rate, measured at 6.5 kg/h, was multiplied by the number of hours the stoker operated per day. As a check, the number of bags of fuel chips burnt daily was recorded (each bag averaged 18.7 kg). Meter readings and operating problems were recorded on monitoring forms.

Monitoring of a TP 2000-30kW Stoker

(continued)

Results

The TP 2000-30kW stoker connected to the Hunter 801B furnace operated very well over the 1987/88 heating season when fueled with sawmill chips. The stoker provided the major share of the Glaude residence heating and maintained comfort level throughout the heating season. The owners welcomed the savings in time associated with chip burning as opposed to roundwood. However, the stoker could be improved if its design incorporated loss of flame detection, burn-back protection and an instruction manual. The stoker operated on a high hold-fire setting for extended periods of time (early fall, spring), and supplied unnecessary heat to the house. This waste heat production could be either minimized by lowering the hold-fire setting or eliminated by incorporating an automatic ignition system. The stoker was capable of a maximum output in the range of 100 MJ/h. This implied that it could easily heat more than twice the area of the Glaude housing; for example, it could supply commercial installations such as a small woodworking shop or greenhouse.

From January 7 to April 2, 1988, the heating system consumed 4355 dry kg of fuel; this indicates a system seasonal efficiency of 49%. The stoker had low particulate emission levels, less than 5 g/h when operated with chips at 35% moisture content. The TP 2000-30kW was able to obtain a maximum burn rate of 9 kg/h of hardwood chips at 60% combustion efficiency. The total cost of the system, including the stoker and furnace was \$6400. If the price of oil was \$0.329/litre, and the appliance was adjusted for an efficiency of 69%, it would pay for itself in 10 years. If the appliance was used at twice the actual output it could be repaid in less than 5 years.

Publications

(1) C. Lemay and G. O'Connor, INSTALLATION AND MONITORING OF A TP 2000-30 KW STOKER, Bioenergy Development Program project no. 6-6260, Energy, Mines and Resources Canada 1988.

Sources of outside financial support for this study included:

Source: EMR
Program: BDP
Proj. No: 6-6260
Value: \$35,994

Scientific Authority: I.B. Flann

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For further information, contact the Efficiency and Alternative Energy Technology Branch, EMR Canada 580 Booth Street, Ottawa, K1A 0E4.

Energy, Mines and Resources Canada/CANMET



Bioenergy Fact Sheet

STUDIES SERIES

Performance Improvement of Roundwood Furnace

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Study Objectives

Two related studies were recently carried out at the Institut de Recherche en Technologie Appropriée (IRTA). The objective of the first project was to modify the combustion chamber of a Surefire roundwood furnace to improve its efficiency and to lower its emissions. At the same time, IRTA improved air tightness and modified the thermostatic control of a Lakewood catalytic furnace. Finally, a report of the procedures and results was provided to Canadian manufacturers. The objective of the second study was to demonstrate how the CSA B415 Performance Standard can be used to improve furnace efficiency of a Surefire from 65 to 79% through the addition of a brick liner and a second catalytic combustor. This study is a continuation of previous work. Refer to BITTS # 50159 PERFORMANCE OF PULPCHIP/ROUNDWOOD BOILERS.

Background and Method

Under the partial load heat demand of most Canadian homes, wood-fuelled systems generally perform poorly because of high emissions. In the first study, the Surefire furnace and the Lakewood catalytic furnace were examined. For the Surefire, the question investigated was whether modifying the combustion chamber would significantly affect combustion and emissions in the 25 MJ/h range. For the Lakewood catalytic furnace, the lack of proper control over combustion air was investigated. The CSA B415 methodology was used by IRTA for the tests. For the Surefire furnace, a series of firebrick configurations were introduced and tested. A double-walled metal plate was installed and tested. Finally, the top of the fire chamber was modified to include a catalytic combustor and bypass, and the appliance was then tested. After assessing the basic performance of the Lakewood catalytic furnace at constant heat output, the unit was disassembled and rebuilt with a new combustion air control system.

START DATE:	07/86
COMPLETION DATE:	11/87
APPLICABILITY:	Residential
TYPE OF BIOMASS:	Forest crop for bioenergy Forest waste/waste timber Mills or factory waste
TYPE OF TECHNOLOGY:	Combustion (grate system)
TOTAL STUDY COST:	\$83,938 (actual)

The second study was carried out using the modified Surefire furnace from the first study. Tests were carried out to confirm the improvement in performance accomplished by adding a continuous metal inner liner to the combustion chamber, and to compare the results to the improvement that can be achieved through the use of various catalysts. The configurations tested included the original design plus brick liner, metal liner, two catalysts, two catalysts and brick liner, and two catalysts and metal liner. Then, using the configuration that proved the most economic, tests were carried out using reduced heat exchanger volume (by 15% and 30%).

Performance Improvement of Roundwood Furnace

(continued)

Results

The first study indicated that the addition of a firebrick liner to the Surefire furnace provides a slight improvement in efficiency and an appreciable reduction (24%) in particulate emissions compared to the original design.

It was found that catalytic combustors provide a large reduction in emissions and a very appreciable increase in efficiency, achieving close to the 80% range. The reduction in particulates for a single catalytic block was 53%, whereas double and triple blocks provided a 65% reduction. The tests demonstrated that the catalyst is less efficient with an unlined firebox than with a lined firebox, and a metal liner is more effective than a firebrick liner. B415 testing showed that in the Surefire B01B, high heat transfer in the firebox gives better performance than with an uninsulated firebox with or without catalytic combustors.

During the tests, IRTA also observed that excessive energy transfer in the heat exchanger leads to condensation in the chimney. Creosote condensate dripped from the flue at all combustion levels below 25 MJ/h. IRTA concluded that the heat exchanger on the appliance is too large for it.

Publications

(1) C. LeMay, SIXTH CANADIAN BIOENERGY R&D SEMINAR, Performance of a Roundwood Furnace at Low Heat Output (15 to 30 MJ/h) by Modification of the Combustion Chamber, I.R.T.A., 1988, pp. 513-516.

(2) C. LeMay, PERFORMANCE IMPROVEMENT OF ROUNDWOOD FURNACES, Bioenergy Development Program project no. 6-6087, Energy, Mines and Resources Canada, 1987.

(3) C. LeMay, FURNACE PERFORMANCE IMPROVEMENT AT LOW HEAT OUTPUT THROUGH USE OF A CONTINUOUS STEEL LINER, Bioenergy Development Program project no. 6-6693, Energy, Mines and Resources Canada, 1987.

Sources of outside financial support for this study included:

Source:	EMR	EMR
Program:	BDP	BDP
Proj. No:	6-6087	6-6693
Value:	\$65,950	\$17,988

Scientific Authority: I.B. Flann

Funding for R&D supported by the Bioenergy Development Program (BDP) was provided by the Interdepartmental Panel on Energy R&D (PERD).

This fact sheet is one of a series. The information has been carefully checked and has been verified at source. The information presented was current as of:

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Energy, Mines and Resources Canada/CANMET



Bioenergy Fact Sheet

STUDIES SERIES

Development of Catalytic Wood-Burning Furnace

Principal Investigator

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Study Objectives

The objectives of this study cover the design, fabrication and testing of a 12-hour catalytic roundwood furnace. This furnace (Prototype No. 6) is based on Prototype No. 5, which was designed and tested under a previous contract. Intecon Technology Limited (formerly 644647 Ontario Limited) are responsible for this project.

START DATE:	09/86
COMPLETION DATE:	05/90
APPLICABILITY:	
Industrial sector	Residential
TYPE OF BIOMASS:	
Forest crop for bioenergy	Forest waste/waste timber
Mill or factory waste	
TYPE OF TECHNOLOGY:	
Combustion(grate system)	
TOTAL STUDY COST:	\$147,200 (estimated)

Background and Method

This study is a continuation of the roundwood catalytic furnace research and development carried out under a previous contract. Prototype No. 5 from the previous study was tested to CSA standard B-415 by the Institut de Recherche en Technologie Appropriée (IRTA) laboratory near Ottawa. The previous contract was successful in that it produced a clean-burning, efficient roundwood furnace, much improved over models currently on the market. However, it was unsuitable for most consumers for two reasons. The unit was too heavy and expensive, and the combustion chamber design made the loading operation difficult. Based on the test results, a sixth prototype was fabricated, concluding the first contract. The present study covers the preliminary testing of Prototype No. 6, subsequent certification testing, fabrication of two units for field testing, and installation and monitoring of these units during the 89/90 heating season.

The previous problems will be addressed in that the new prototype will be only half as large, resulting in a significant reduction in weight and cost, as well as decreased emission levels. The primary chamber was reduced in volume to approximately half of the existing size, reducing the burn-time for a full load of fuel to 13 hours at high burn rates. The circular cross-section of the catalyst pipe was changed to a rectangular shape, extending the width of the primary chamber and thus eliminating the fuel loading difficulties. The external packaging of the units and the blower cabinet were further refined, including a reduction in steel thickness in order to further reduce weight and cost. Minor modifications may be made based on results from monitoring.

Development of Catalytic Wood-Burning Furnace

(continued)

Results

Based on testing to date in the Ryerson Lab, the performance of Prototype No. 6 has proven to be generally comparable to that of Prototype no. 5, and in some respects may be superior. Preliminary analysis of test data has indicated higher overall efficiency.

The unit has been returned to Lakewood Manufacturing and the following changes have been made:

- intake tube area has been reduced to one-half the design value;
- intake ports (into primary chamber) have also been reduced;
- and - various shortcomings discovered during testing were repaired.

From Lakewood, the unit was shipped to IRTA in Ottawa for testing. IRTA is in the process of installing the unit in the test stand.

Publications

(1) DEVELOPMENT OF A CATALYTIC WOOD BURNING FURNACE, Bioenergy Development Program project no. 5-7285, Energy, Mines and Resources Canada, 1987.

(2) REFINEMENT OF CATALYTIC FURNACE DESIGN, Bioenergy Development Program project no. 7-6188, Energy, Mines and Resources Canada, 1988.

Sources of outside financial support for this study included:

Source:	EMR	EMR	EMR
Program:	BDP	BDP	BDP
Proj. No:	5-7285	7-6188	8-9005
Value:	\$62,000	\$48,000	\$37,200

Scientific Authority: J.M. Charron

Funding for R&D supported by the Bioenergy Development Program (BDP) was provided by the Interdepartmental Panel on Energy R&D (PERD).

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Energy, Mines and Resources Canada/CANMET



Bioenergy Fact Sheet

STUDIES SERIES

Roundwood-Fuelled Residential Heating Systems

Principal Investigator

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Study Objectives

In this study the performance characteristics of two residential wood-fired heating systems were evaluated over the course of a full heating season. Both systems use hot water heat storage in order to improve efficiency, and both have a hydronic heat distribution system. The project was carried out by IEA Consulting of Charlottetown, PEI.

START DATE:	02/85
COMPLETION DATE:	08/86
APPLICABILITY:	
Industrial sector	Residential
TYPE OF BIOMASS:	
Forest crop for bioenergy	Forest waste/waste timber
Mill or factory waste	
TYPE OF TECHNOLOGY:	
Combustion(grate system) *	
TOTAL STUDY COST:	\$32,011 (actual)

Background and Method

The two heating units chosen for this study were a 332 MJ/h (350,000 Btu/h) Tempest system built by Dumont Industries of Maine, and a 95 MJ/h (100,000 Btu/h) Jetstream system manufactured by Kerr Controls of Nova Scotia. Both systems use water for heat storage, and both designs are based on the work of Prof. Richard Hill of the University of Maine. In essence, combustion takes place at high temperatures and with high efficiency (and low creosote formation), but heat is transferred to the house at a much slower rate by means of the heat storage medium, in this case water. The Jetstream system was installed in a Nova Scotia home. Three tanks with a total of 4000 litres storage were installed adjacent to the boiler. The storage tanks were boxed-in, fibreglass insulation blown-in, and a connection made to the existing oil-fired burner for backup. A second expansion tank was added during the winter. The combustion chamber of the Tempest has a large diameter and volume, allowing the loading of a substantial quantity of wood and long intervals between firing.

In this design, a fan force-feeds air to the base of the fire through a combustion air tube, producing a strong draft through the boiler to the chimney. Temperatures in the turbulent fire approach 1150 degrees Celsius, completely burning the wood, including all of the creosote-forming gases. Heat meters were installed to determine heat flows to the house radiators from the storage tanks. The mass of wood used and the heat content were determined. A portable moisture meter was used to check the moisture content of the wood.

Roundwood-Fuelled Residential Heating Systems

(continued)

Results

The most important data obtained from this monitoring program were values for thermal efficiency of the boilers, the thermal storage and the system as a whole. Over one year, the Jetstream used 22.5 tonnes of wood at an average moisture content of 22.2%, and the Tempest used 79.4 tonnes at an average moisture content of 28%. The Tempest was fired-up 182 days using an average load per day of 436 kg, and the Jetstream operated 171 days using an average load per day of 131 kg.

The efficiency of the Tempest boiler was measured at 50%, and the storage system at 97%. The Jetstream efficiency was higher at 55%, probably due to the use of drier fuel. These efficiencies appear to be low, but compare well with those calculated for other wood-fired combustion units.

This study has shown that the direct radiant heat transfer of a wood stove used for space heating is more efficient, but cannot offer the distribution of heat possible with a central heating system. It is felt that the heat storage concept offers many advantages in a well-designed system, but the high capital cost and the large space requirement for the tank are serious disadvantages.

Publications

(1) PERFORMANCE STUDY OF TWO ROUNDWOOD-FUELLED CENTRAL HEATING SYSTEMS INCORPORATING LARGE HEAT STORAGE TANKS, Bioenergy Development Program project no. 4-6317, Energy, Mines and Resources Canada, 1986.

Sources of outside financial support for this study included:

Source: EMR
Program: BDP
Proj. No: 4-6317
Value: \$32,011

Scientific Authority: I.B. Flann

Funding for R&D supported by the Bioenergy Development Program (BDP) was provided by the Interdepartmental Panel on Energy R&D (PERD).

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Energy, Mines and Resources Canada/CANMET



Bioenergy Fact Sheet

STUDIES SERIES

Evaluation of PEI Chip-Burner Demonstrations

Principal Investigator

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Fax:

Study Objectives

The objective of this study was to survey the degree of homeowner satisfaction with a Firefly chip/sawdust burning appliance after three years of user experience. IEA Consulting Group Ltd. was the proponent for this study.

START DATE:	01/84
COMPLETION DATE:	01/85
APPLICABILITY:	Residential
TYPE OF BIOMASS:	Forest crop for bioenergy Forest waste/waste timber Mill or factory waste
TYPE OF TECHNOLOGY:	Chipping Combustion(grade system)
TOTAL STUDY COST:	\$23,817 (actual)

Background and Method

The Institute of Man and Resources was responsible for the installation of 30 Firefly residential chip/sawdust burning appliances in rural areas of Prince Edward Island in 1981. In order to assess the success of these units three years later, an interview and inspection project was conducted in 1984/85 by IEA Consulting Group Ltd.

Evaluation of PEI Chip-Burner Demonstrations

(continued)

Results

Attention during the inspection focused on the tunnel from the burner to the boiler and the hopper for the chips. Corrosion damage was a problem with the hopper.

The homeowners were generally satisfied with the burners, but the Firefly could not meet CSA standards and has been removed from the market. A number of the original 30 installations are still in operation; however, most of them are burning roundwood or sawdust due to maintenance problems with chippers.

Publications

(1) A REVIEW OF HOMEOWNER EXPERIENCE, Bioenergy Development Program project no. 4-6196, Energy, Mines and Resources Canada, 1985.

Sources of outside financial support for this study included:

Source: EMR
Program: BDP
Proj. No: 46196
Value: \$23,817

Scientific Authority: I.B. Flann

Funding for R&D supported by the Bioenergy Development Program (BDP) was provided by the Interdepartmental Panel on Energy R&D (PERD).

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Energy, Mines and Resources Canada/CANMET



Bioenergy Fact Sheet

STUDIES SERIES

Woodchip Furnace Performance Evaluation

Principal Investigator

G. Stiles

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Phone:

Fax:

Study Objectives

The objective of this study was to monitor and assess the combustion efficiency and operating performance of three SVEMO auto-feed chip burners operating in Newfoundland. Island Energy Associates Ltd. was the proponent for this project.

START DATE:	08/84
COMPLETION DATE:	09/85
APPLICABILITY:	
Industrial sector	Commercial sector
TYPE OF BIOMASS:	
Forest crop for bioenergy	Forest waste/waste timber
Mill or factory waste	
TYPE OF TECHNOLOGY:	
Combustion (grate system)	
TOTAL STUDY COST:	\$21,500 (actual)

Background and Method

Three SVEMO auto-feed chip burners operating in Newfoundland were monitored to assess their operating performance. A 0.53 GJ/h (500,000 Btu/hr) unit was installed in a free-standing concrete block boiler house in Arnold's Cove to provide hydronic heating for a truck servicing depot. A 0.26 GJ/h (250,000 Btu/hr) unit installed in Baie Verte provides hydronic heating for a 10-unit apartment building. A similar unit provides hot air heating for a heavy equipment servicing warehouse in Bishop's Falls. The chip burners are capable of handling green or dry particulate wood residues such as chips, shavings, sawdust, and bark, up to a size of 5 cm (2 in).

The units were monitored to determine net energy input, net energy provided to the heating system, combustion efficiency, and overall performance including general operating characteristics.

The project included monitoring of the systems from start-up through a complete heating season, with readings taken on a weekly basis using a bulk measurement technique. The systems were monitored intensively during two weeks of the coldest part of the winter, during which readings were taken daily and precise consumption records were kept.

Woodchip Furnace Performance Evaluation

(continued)

Results

The three woodchip burners had output efficiencies ranging between 33% and 40%, with a further 25% in jacket losses (based on the Arnold's Cove calculations). The combustion efficiencies at Baie Verte and Bishop's Falls were 63.7% and 65% respectively. Efficiency could not be determined accurately at Arnold's Cove because of an electrical fault in the burner fan control. The electrical fault caused the fan to cut in for 2.5 minutes and then out for a similar period, preventing the completion of accurate combustion efficiency tests. The efficiency appears to be more closely associated with the nature of the furnace installation than with the type of wood fuel burned. The Bishop's Falls installation is tied into the side of the furnace near the stack exit. The flame shoots across the 61 cm (2 ft) width and deflects upward causing excessively high temperatures in the stack, which resulted in greater jacket and stack losses. The Arnold's Cove furnace is very large and uninsulated, allowing a tremendous amount of heat to be lost to the boiler room.

The Baie Verte furnace had the highest delivered efficiency, but had an ash fallout problem. Monitoring of the three SVEMO woodchip burners led to a number of recommendations for future use of these units. Suggestions include triple checking the control systems before leaving the factory, the incorporation of a simple manual method to shut the systems down at night, and a method of limiting the operation of the fire prevention system. Future installations should include increased efforts either to re-capture heat from jacket losses, or to limit these losses by improved pipe and boiler insulation. Overall, it appears that woodchip furnaces can operate at sufficiently high combustion efficiencies to warrant their use as back-up to oil-fired systems, but only if chips are cheaply and readily available in the region. At the same time, potential users should note the high standby losses encountered, which are a function of the type of installation rather than of inherent inefficiencies in woodchip combustion. Future installations of this sort must adhere to the same standards as those applied to oil combustion units.

Publications

(1) J. Stiles, PERFORMANCE EVALUATION OF THREE FURNACES, Bioenergy Development Program project no. 4-6154, Energy, Mines and Resources Canada, 1985.

Sources of outside financial support for this study included:

Source: EMR
Program: BDP
Proj. No: 4-6154
Value: \$21,500

Scientific Authority: I.B. Flann

Funding for R&D supported by the Bioenergy Development Program (BDP) was provided by the Interdepartmental Panel on Energy R&D (PERD).

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Energy, Mines and Resources Canada/CANMET



Bioenergy Fact Sheet

STUDIES SERIES

Wood Burning Boiler Inventory

Principal Investigator

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Study Objectives

The objective of this project is to establish a national inventory of installations comprising wood-burning boilers with a steam generating capacity of at least 18,000 kg/h. The database will contain process and design information.

MacLaren Plansearch Inc. of Toronto is responsible for the development of this project.

START DATE:	03/88
COMPLETION DATE:	12/89
APPLICABILITY:	
Industrial sector	Commercial sector
TYPE OF BIOMASS:	
Forest crop for bioenergy	Forest waste/waste timber
Mill or factory waste	
TYPE OF TECHNOLOGY:	
Combustion (grate system)	Fluidized bed combustion
Combustion (suspension)	Combustion
TOTAL STUDY COST:	\$87,462 (estimated)

Background and Method

The type and geographic distribution of large-scale wood-burning boiler installations (WBI) in Canada must be known in order to determine the potential for technological advancement in this field. This project traces the location of as many WBIs as possible through the Canadian Boiler Association, boiler manufacturers, the pulp and paper industry, government ministries, etc. Through contact with each firm, information will be obtained by questionnaire and a computerized inventory established. This task represents Phase I of the project.

Phase II involves the evaluation of each installation followed by a review of the potential to improve combustion.

The results will be used to determine the energy produced by wood-burning boiler installations in Canada by region and industry type, as well as the equivalent oil replacement value. In addition, the information gathered from the study will focus attention on the areas where further research and development are needed.

Wood Burning Boiler Inventory

(continued)

Results

The database will provide an inventory by size range of wood-fired boilers producing steam operating in Canada. It will contain information on the quantities of wood burnt in order to determine if any remaining capacity of individual boiler systems exist. The database and inventory will attempt to determine if the present steam production is limited by design, operational requirements or by ancilliary equipment.

The overall inventory of the boiler population will also allow estimates of environmental performance of biomass units to be quantified.

Publications

Sources of outside financial support for this study included:

Source: EMR
Program: BDP
Proj. No: 7-6020
Value: \$87,462

Scientific Authority: J.E. Robert

Funding for R&D supported by the Bioenergy Development Program (BDP) was provided by the Interdepartmental Panel on Energy R&D (PERD).

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For further information, contact the Efficiency and Alternative Energy Technology Branch, EMR Canada 360 Booth Street, Ottawa K1A 0E4.

Energy, Mines and Resources Canada/CANMET



Bioenergy Fact Sheet

STUDIES SERIES

Inspection of Stoves Used in Whitehorse Study

Principal Investigator

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Study Objectives

The main objective of this study was to determine the causes of failure of two stoves used in the Whitehorse Demonstration Project. More specific objectives were the evaluation of the integrity of key components within the emission control system of the catalytic woodstove; and the assessment of the emission reduction performance of the catalytic combustors in the stoves under laboratory conditions. Omni Environmental Services, Inc. was the proponent for this study.

START DATE:	08/87
COMPLETION DATE:	10/87
APPLICABILITY:	
Industrial sector	Residential
TYPE OF BIOMASS:	
Forest waste/waste timber	
TYPE OF TECHNOLOGY:	
Combustion(grate system)	
TOTAL STUDY COST:	\$11,795 (actual)

Background and Method

During the 1986-1987 heating season, a study was conducted in Whitehorse, Yukon Territory, to evaluate the emission and efficiency performance of several new woodheat technologies. Oregon-certified Blaze King 'King' (Model KEJ 1101) woodstoves were installed in two Whitehorse residences identified as homes W07 and W11. At the end of the 1986-87 heating season, the emission control system of each woodstove was inspected and the catalytic combustors (Panasonic 'Honeycomb') were removed and replaced with Corning 'Long Life' combustors. The woodstove originally installed in Home W07 was used during the 1987-88 heating season with no changes to the emission control system. The woodstove originally installed in Home W11 was removed prior to the start of the 1987-88 heating season and replaced with a new Blaze King 'King' due to the warpage of the combustor seat. The replacement stove in Home W11 was used throughout the 1987-88 heating season.

A second inspection of the woodstoves in Homes W07 and W11 was conducted at the end of the 1987-88 heating season. Catalytic combustors used during the 1987-88 heating season (Corning 'Long Life') were also removed for further emission performance evaluation.

Inspection of Stoves Used in Whitehorse Study

(continued)

Results

A detailed inspection of the entire emission control system was conducted on the stove in Home W07. This inspection included the catalyst, the bypass damper mechanism, the thermostat control system, the primary, secondary, and tertiary air supply systems, and all gaskets. Inspection of the bypass door assembly revealed a build-up of approximately 3.8 cm of creosote and ash. The gasket inspection revealed that 15.2 cm of its front edge was missing, with the remaining portion very loose on the front edge. The gasket material on both sides of the bypass damper door mechanism was loose and partially twisted. Two weld gaps, each approximately 0.238 cm, were observed on the bypass damper doors. An inspection of the gasket material in the vicinity of the weld gaps did not reveal any indication of the escape of combustion gases through the weld gaps. The secondary air tube assembly was carefully removed so that a light leak check of the Interam (TM) gasket around the catalyst could be conducted. No light leakage was observed around the gasket, however, approximately 20% of the combustor cells appeared to be blocked with light gray ash material.

The combustor (Corning 'Long Life') was removed to observe the condition of the Interam (TM) gasket around the front and sides of the catalyst. There appeared to be no gaps in the combustor gasket. However, the wash coat on the combustor was peeling in several locations in the upper one-third of the combustor. The combustor seat was also warped in several locations, and what appeared to be thermal stress cracks were observed throughout the combustor seat. The thermostat assembly was removed from the stove and inspected. It was discovered that a set screw which determines the amount of tension on the bimetallic thermostat coil was improperly set according to approved drawings. As with the woodstove in Home W07, a detailed inspection of the entire emission control system for Home W11 was conducted. The inspection revealed only one potentially significant problem. The weld holding the upper plate of the secondary air manifold was cracked at the same location as discovered in the stove in Home W07. However, the plate was not warped. No other defects were uncovered in the inspection.

Publications

Sources of outside financial support for this study included:

Source: EMR
Program: BDP
Proj. No: 7-6155
Value: \$11,795

Scientific Authority: I.B. Flann

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Energy, Mines and Resources Canada/CANMET



Bioenergy Fact Sheet

STUDIES SERIES

Improvements to Biomass Combustion Systems

Principal Investigator

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Study Objectives

The objective of this project is to develop recommendations and guidelines for appropriate control technology for small-to medium-scale biomass combustion systems, in order to increase efficiency and reduce emissions. The study has been initiated in response to both lack of information and concern over the amount and types of emissions from biofuel-fired systems. Both particulate and gaseous emissions will be monitored and analysed during the project. ORTECH International is the proponent for this study.

START DATE:	01/89
COMPLETION DATE:	09/90
APPLICABILITY:	
Industrial sector	Commercial sector
Institutional sector	
TYPE OF BIOMASS:	
Not specific to a type of biomass	
TYPE OF TECHNOLOGY:	
Combustion(grate system)	
TOTAL STUDY COST:	\$245,000 (estimated)

Background and Method

The first of two parts to this project involves the monitoring of flue gases from an existing biomass-fired steam boiler, and correlation of the results with those obtained from the Biomass Combustion Test Facility operated by ORTECH International (formerly the Ontario Research Foundation).

The ORTECH mobile stack sampling unit will be set up at the Chaleur Regional Hospital in Bathurst, New Brunswick, which operates a 3 MW wood-chip-fired steam boiler. Over a 3-day period flue gases from the boiler will be monitored for Ox, NOx, SOx, COx, THC and fly ash particulates, together with flue temperatures, moisture content and flow rates. Two test fuels are to be used during the tests -- wood chips and hog fuel -- and the boiler is to be operated at both high and low firing rates for each fuel. The monitoring equipment will then be used for correlation testing at the ORTECH facility, using samples of the same fuel obtained from the field site.

Part two of this project will involve the investigation of automatic controls for small-to medium-scale biomass combustion units. A review of current technology and technical literature will be carried out by ORTECH, along with an analysis of relevant control parameters based on monitoring results from part one of the work. This program will enable ORTECH to develop design guidelines for control systems, for supply to commercial manufacturers.

Improvements to Biomass Combustion Systems

(continued)

Results

Field monitoring is expected to be carried out in January 1990, with correlation testing at ORTECH to follow in March 1990.

Publications

Sources of outside financial support for this study included:

Source: EMR
Program: BDP
Proj. No: 8-6183
Value: \$175,000

Scientific Authority: J.E. Robert

Funding for R&D supported by the Bioenergy Development Program (BDP) was provided by the Interdepartmental Panel on Energy R&D (PERD).

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Energy, Mines and Resources Canada/CANMET



Bioenergy Fact Sheet

STUDIES SERIES

Biomass Combustion Test Facility

Principal Investigator

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Study Objectives

The overall objective of this study was the development of a state-of-the-art biomass combustion facility to conduct research and development on the various subsystems using biomass fuels available in Canada.

The long-term objective of this study is to promote awareness of the potential for biomass fuels as substitutes for hydrocarbon fuels, as well as to establish a dedicated research and development facility which can be used by appropriate members of the bioenergy community. ORTECH International was the proponent for this study.

START DATE: 08/86

COMPLETION DATE: 05/89

APPLICABILITY:

Industrial sector

Agricultural sector

Commercial sector

Institutional sector

TYPE OF BIOMASS:

Peat

Mill or factory waste

TYPE OF TECHNOLOGY:

Combustion(grate system)

TOTAL STUDY COST: \$291,312
(actual)

Background and Method

To realize the objective of this study, it was necessary to establish a credible test facility and to make its existence known to those people who might benefit from its use. ORTECH performed an internal study to identify critical variables which will have an impact on increased utilization of Canadian biomass resources as an alternative to conventional fuels. The study led to the preliminary selection of the major components required to develop a workplan and to implement a test facility. The workplan consisted of the finalization of the designing requirements for a biomass research facility; a review of the instrumentation requirements for the facility; the installation of necessary equipment; the identification of suppliers for the five fuel types; the assembling of the unit as an extension to ORTECH's existing combustion facility; and the performing of tests using sample test fuels and analysis to quantify stack emissions, system performance and ash characteristics.

The following five biomass fuels were evaluated: densified biomass-derived fuel pellets (Energen or similar pellets processed by Canadian suppliers); green hardwood sawdust typical of that generated at sawmills with a moisture content of 51%; dry softwood sawdust typical of waste generated by furniture factories with a moisture content of 17%; mixed green wood chips (hog fuel) typical of that generated from municipal chipping operations with a moisture content of 35%; and fuel peat procured from a production site located in New Brunswick. The milled peat was tested as received with a moisture content of 45% and a Von Post humus value of H5 to H6.

Biomass Combustion Test Facility

(continued)

Results

In general it was found that the efficiency of the combustion system ranged from 55% to 65% for the fuels tested. Sensible heat losses ranged from 13% to 20% of the energy input and latent losses were 10% to 25%. Efficiency improvements were realized through exhaust gas thermal recovery. A condensing-type heat exchanger yields the highest recovery and may provide additional benefits by reducing particulate and condensable emissions. Maximum system firing rates were achieved with green wood chips and densified wood pellets. The two sawdust fuels and fuel peat fired at 50% to 60% of the design capacity and released high emissions of carbon monoxide. It is suspected that fuel particle size is the most significant factor affecting the performance of these fuels, although improvements may be realized by optimization of the combustion cell. Modifications to the grate system would be required to effectively increase the surface area exposed to underfire air, thereby providing more uniform combustion.

At the same time, channeling and fly ash generation would be reduced as a result of lower underfire air velocities. Application of automatic stoker-fed combustion systems in the smaller size ranges may cause dramatic shifts in performance as a result of changing operational conditions, i.e. fuel composition, mass feed rate, load, etc. This was frequently observed during the fuels testing program and is cause for concern for applications requiring unattended operation. Control strategies should be investigated and hardware developed to provide integrated systems which will adjust for common operational variables.

Publications

- (1) ORTECH Newsletter publication, TECHNOLOGY TODAY, Vol. 30, Nov. 2, 1987, pp. 3.
- (2) ORTECH promotional brochure, BIOMASS COMBUSTION FACILITY.
- (3) M.B. Shaw, Development and Commissioning of a Biomass Combustion Test Facility and Characterization of Five Canadian Abundant Biomass Fuels, SEVENTH CANADIAN R&D SEMINAR, ORTECH International, 1989, pp. 591.

Sources of outside financial support for this study included:

Source: EMR
Program: BDP
Proj. No: 6-6181
Value: \$187,312

Scientific Authority: J.E. Robert

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580 Booth Street, Ottawa K1A 0E4.

Energy, Mines and Resources Canada/CANMET



Bioenergy Fact Sheet

STUDIES SERIES

Effects of Wood Stove Catalyst on Air Quality

Principal Investigator

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Study Objectives

The general objective of the project was to determine the effects of catalyst performance on room air quality from the operation of a typical woodstove under both normal and reduced draft conditions. The unit is installed as an insert and as a free-standing stove and was tested at two different burn rates. Ryerson Polytechnical Institute was the proponent for this study.

START DATE: 10/85

COMPLETION DATE: 08/88

APPLICABILITY:

Residential

TYPE OF BIOMASS:

Forest crop for bioenergy

Forest waste/waste timber

Mill or factory waste

TYPE OF TECHNOLOGY:

Combustion (grate system)

TOTAL STUDY COST:

\$54,473
(actual)

Background and Method

The stove under test was a representative, well designed fireplace insert produced by a reputable manufacturer in Ontario. The unit has a nominal maximum output of approximately 25 kW or 85,000 BTU/h and is equipped with a variable speed blower for recovery of heat.

The installation of the unit was such that approximately 2/3 of the unit was enveloped in the fireplace cavity, leaving 1/3 of the outer surface exposed to the room providing natural convection of useful heat in addition to the heat provided by the blower.

The insert was tested in the calorimetric room at Ryerson using a simulated fireplace cavity fabricated of drywall. Back-losses (power) from the insert were measured using air flowing through an auxiliary chamber behind the fireplace wall. Any spillage of gases from the front or the back of the insert was collected in the room sampling.

In addition to the necessary thermodynamic measurements required by the calorimetric method of performance evaluation, measurements were made of stack gas emissions using continuous gas analysis and particulate emissions using heated filters designed and built at Ryerson.

Flue gases were collected semi-isokinetically through a heated sample tube and fed through a water removal and collection system (except for the CH₄ line which remained heated) to the analyzer console.

Ambient gas sampling was achieved through teflon tubing kept at room temperature. Calibration was achieved in the normal fashion using zero and span gases in conjunction with the manufacturer's calibration curves, and with due regard for interfering gases.

Effects of Wood Stove Catalyst on Air Quality

(continued)

Results

Continuous measurement of CO and THC was achieved using gas analyzers, while batch methodology was used to determine PAH concentrations. The main thrust of the work was carried out in the calorimetric lab at Ryerson Polytechnical Institute, and the PAH analysis was the responsibility of Health and Welfare Canada.

The original deliverables of the project were not realizable with the attempted methodology and the associated instrumentation.

The two main sources of difficulty in the ambient measurements were atmospheric and environmental variables beyond the control of the research team and limitations in the instrumentation.

The PAH phase was limited by low concentrations beyond the detection limits of the methodology. Due to the large amounts of staff time required to carry out the analysis and interpretation of the data, the cost-effectiveness of the results were questionable at best.

The technical difficulties reported indicate that the method of measuring ambient gas concentrations with the type of instrumentation employed in this study must be radically changed in any future work. Batch methods may be the only alternative.

The original objective of this study to determine a dynamic picture of room loading in relation to catalytic operation is highly challenging and may not be attainable in a cost-effective manner.

Publications

(1) E.A. Fernbach, R.A. Guerriere, EFFECT OF WOOD STOVE CATALYST CONDITION AND OPERATION ON THE NATURE OF PAH, THC AND CO CONTENT OF INDOOR POLLUTION AND STACK EMISSIONS, Bioenergy Development Program project no. 5-7192, Energy, Mines and Resources Canada, 1988.

Sources of outside financial support for this study included:

Source: EMR
Program: BDP
Proj. No: 5-7192
Value: \$54,473

Scientific Authority: I.B. Flann

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Energy, Mines and Resources Canada/CANMET



Bioenergy Fact Sheet

STUDIES SERIES

Gas Mixing in Wood-Waste-Fired Boilers

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Study Objectives

The objective of this project was the development of mathematical design tools needed for improved gas mixing in wood-waste-fired boilers. It is believed that improved gas mixing will lead to increased thermal efficiency and reduced particulate emissions. Sandwell Swan Wooster Inc. was the proponent for this study.

START DATE:	02/88
COMPLETION DATE:	07/89
APPLICABILITY:	Industrial sector
TYPE OF BIOMASS:	Municipal solid waste Mill or factory waste Forest waste/waste timber
TYPE OF TECHNOLOGY:	Combustion(grate system)
TOTAL STUDY COST:	\$59,500 (estimated)

Background and Method

For the last two years, Sandwell has been working on improving gas mixing in kraft recovery boilers to achieve better performance. The principles on which this technology is based apply equally to wood-waste-fired boilers (WWFBs), and should be of value in mass burn energy-from-waste (EFW) facilities. The work on recovery boilers has shown that there is a major deficiency in the traditional methods for introducing air into the furnace. The jets are too small to have sufficient momentum to penetrate the upflowing combustion of gases and are usually arranged so they inherently interfere with each other. Sandwell has developed design concepts for improving gas mixing in recovery boilers and WWFBs. These concepts were developed to allow the desired quantity of air to be delivered where it is needed in the furnace, with good mixing of the air and fuel volatiles, but without significant velocity extremes. By applying these concepts, it should be possible to considerably reduce the flame size, concentrating the flame in a small area immediately above the grate.

Improved gas mixing would provide the more important benefits offered by external wood-waste dryers, but at a fraction of the cost. It would reduce the need for fossil fuel support, improve thermal efficiency, decrease particulate and hydrocarbon emissions, and lead to a greater load-swing capability. The general scope of the project therefore involved the preparation of a general computer program from the mathematical expressions developed from air-jet behaviour in kraft recovery boilers, and the conversion of this program for use with WWFBs.

Gas Mixing in Wood-Waste-Fired Boilers

(continued)

Results

The generalized calculations will be applicable to most boilers burning wood-waste, coal, oil, gas, sludge or any combination.

Sandwell Swan Wooster Inc. is presently seeking an industrial participant to provide a wood-waste-fired boiler to serve as an example case for the computerized heat and mass balances and the computerized jet calculations.

The novel gas mixing concepts will be easily implemented on some wood-waste-fired boilers.

Publications

Sources of outside financial support for this study included:

Source: EMR
Program: BDP
Proj. No: 7-6023
Value: \$50,000

Scientific Authority: J.E. Robert

Funding for R&D supported by the Bioenergy Development Program (BDP) was provided by the Interdepartmental Panel on Energy R&D (PERD).

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For further information, contact the Efficiency and Alternative Energy Technology Branch, EMR Canada 580 Booth Street, Ottawa, K1A 0E4.

Energy, Mines and Resources Canada/CANMET



Bioenergy Fact Sheet

STUDIES SERIES

Boiler Test Program

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Study Objectives

The primary objective of the research project was to determine the effects of various operational parameters on the operation of wood-fired boilers in order to provide more knowledge on solid and gaseous emissions, basic combustion processes, and improved sampling and analysis procedures for wood refuse used as fuel. SNC Research Corporation was the proponent for this study.

START DATE:	11/84
COMPLETION DATE:	02/87
APPLICABILITY:	Industrial sector
TYPE OF BIOMASS:	Forest waste/waste timber Mill or factory waste
TYPE OF TECHNOLOGY:	Combustion(grate system)
TOTAL STUDY COST:	\$304,000 (actual)

Background and Method

In a previous project funded through the ENFOR program (C-235), a series of tests were conducted on boilers at three different sites. This BDP funded project 4-6203 represents the fourth test program in the series, conducted on a wood refuse and oil-fired boiler at a multi-product forest industry mill on Vancouver Island, B.C.

The boiler tested was the most recent power boiler installed at that time at the mill, which feeds a main header in parallel with a number of smaller older units which also fire wood. The boiler was selected because of its unique furnace design, innovative use of arches and combustion air supply provisions, and wider furnace dimensions. The maximum continuous rating steam flow of the boiler was 50.4 kg/s (400,000 lb/h); however, the unit could quite comfortably be operated at 56.7 kg/s (450,000 lb/h) on wood alone.

A total of six runs were conducted on the boiler at different operating conditions and samples such as wood refuse, gas and particulate emissions were collected at fifteen locations in the boiler plant.

Boiler Test Program

(continued)

Results

The following conclusions were drawn from the Boiler test program carried out at the mill. The wood refuse moisture contents ranged from 55-58%. 95% of the wood sample weight were below 25.4 mm in size. Approximately 50% of the sample weight was below 6.35 mm in size. More fines in the wood refuse fuel resulted in higher particulate concentration in the flue gases. The potentially harmful elements, nickel, chromium, vanadium, and mercury, were present in negligible quantities in the wood refuse ash. The furnace temperatures closest to the gate were in the 790-850 degrees Celsius range, and 770-800 degrees Celsius further up in the furnace. Furnace temperatures adjacent to the walls were about 30-60 degrees Celsius lower than temperatures at the middle of the furnace. Increasing steam load, from 50.4 to 61.5 kg/s, increased particulate concentration in the flue gases at the boiler outlet from 5395 mg/SDCM to 8048 mg/SDCM. Oil firing significantly suppressed the carry-over of particulate into the furnace.

SO₂ levels in the flue gases were less than 50 ppm irrespective of whether wood firing or oil-and-wood combined firing were employed. Flue gas temperatures at the boiler outlet, air preheater outlet and dust collector outlet were higher for greater steam loads. The boiler efficiency did not suffer when steam load was increased or when fuel quality varied. Small variations in the boiler efficiency were mainly due to loss of combustibles in the carry over of particulates. The boiler efficiencies ranged between 61-66%. Fuel moisture greater than 62% had a considerable impact on the boiler's ability to sustain an upward swing. A continuous moisture monitor on the wood stream to the boiler was found to be essential for optimal performance.

Publications

(1) COMBUSTION AND EMISSION RESEARCH ON WOOD-REFUSE BOILERS, Bioenergy Development Program, ENFOR No. C-235A - C-235H, Energy, Mines and Resources Canada.

(2) BOILER TEST AT ELK FALLS, B.C., Bioenergy Development Program project no. 4-6203, Energy, Mines and Resources Canada, 1987.

Sources of outside financial support for this study included:

Source: EMR
Program: BDP
Proj. No: 4-6203
Value: \$254,400

Scientific Authority: G. Lee

Funding for R&D supported by the Bioenergy Development Program (BDP) was provided by the Interdepartmental Panel on Energy R&D (PERD).

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Energy, Mines and Resources Canada/CANMET



Bioenergy Fact Sheet

STUDIES SERIES

Vallsta Self-Igniting Wood Chip Stoker

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Study Objectives

The objective of this project was to evaluate the operating performance of a wood-chip-fuelled Vallsta stoker which produces domestic hot water in a residential installation. The reliability, durability, ease and convenience of routine operation of the appliance were to be assessed. In addition, the efficiency of the appliance and its ability to cleanly burn fuel were to be identified and potential system modifications recommended to improve appliance performance. The University of New Brunswick, Department of Forest Engineering was the proponent for this study.

START DATE:	01/86
COMPLETION DATE:	11/86
APPLICABILITY:	
Commercial sector	Institutional sector
Residential	
TYPE OF BIOMASS:	
Forest crop for bioenergy	Forest waste/waste timber
Mill or factory waste	
TYPE OF TECHNOLOGY:	
Combustion(grate system)	
TOTAL STUDY COST:	\$17,584 (actual)

Background and Method

The Vallsta stoker was designed to burn relatively small dry wood chips of about 12mm square by 3mm in thickness and having 30% or less moisture content. The Swedish made appliance was rated at 40 kW. The unit consisted of a circular fuel hopper with a discharge auger that conveyed fuel to a perforated inclined grate mounted on the discharge end of the auger housing. A forced-draft fan blew combustion air up through the grate and into the fuel. A 1200 W electric heating coil mounted directly beneath the grate was used to ignite the fuel automatically. A microprocessor-based control system incorporated field-adjustable timers to accommodate various fuel characteristics, and also used a photo cell to monitor the fire. A thermally-activated water deluge system was fitted to the fuel-feed auger to extinguish the fire should burn-back take place. The Vallsta stoker was used with a CTC boiler for a three-week test period during which the system was used to produce domestic hot water only. Mass fuel flow rates were determined using various fuel types and moisture contents.

The gross energy input to the appliance was then calculated using the higher heating value of the fuel. Energy output from the boiler was measured using calibrated integrating energy meters in the hot water circuits. The overall appliance efficiency was calculated by dividing the measured energy output over an appropriate time period by the gross energy input associated with the mass of dry fibre supplied over the same period. Combustion efficiency was determined by measuring the percentage of carbon dioxide in the stack gas and the stack gas temperature.

Vallsta Self-Igniting Wood Chip Stoker

(continued)

Results

The Vallsta stoker (benefiting from several years of development and in-service testing in a relatively large number of Scandinavian installations) performed very reliably over the test period. The fuel feed auger stalled only once as a result of irregular sized fuel particles jamming the feed system. The open inclined grate tended to shed large non-combustibles, and fine particles were blown off the grate by the primary air. The overall system efficiency varied between 26.9% and 47%, and appeared to be inversely related to the stoker run-time control setting. The measured combustion efficiency ranged between 72% and 83% with a smoke number of 5. Attempts to fuel the appliance with two readily available mill-residues (for which the Vallsta is not designed) yielded unanticipated results. The first fuel tested consisted of hardwood sawdust which tended to blow off the grate before it could ignite. The material fell into the ash pit where it eventually burned, but not as cleanly as if it had burned on the grate.

Hardwood shavings were also tested as a fuel. This material often failed to flow from the hopper despite the action of the stirring wheel. Burning shavings required frequent manual agitation of the fuel in the hopper to ensure flow into the feed auger, and they tended to burn back along the auger after the stoker had been turned off. During burn back, the water deluge system operated effectively. Indirectly this caused an electrical short circuit which damaged the printed circuit board in the control panel. It was concluded that the Vallsta control system should incorporate a two-pole relay to completely de-energize certain circuits on shut-down, rather than the single-pole relay that was used.

Publications

(1) C.A. Short, SIXTH CANADIAN BIOENERGY R&D SEMINAR, Evaluation of Four Wood-Chip-Fueled Appliance for Residential Heating, University of New Brunswick, 1988, pp. 508-512.

(2) C.A. Short, PERFORMANCE TESTING OF A VALLSTA SELF-IGNITING WOOD CHIP STOKER, Bioenergy Development Program project no. 5-7255, Energy, Mines and Resources Canada, 1986.

Sources of outside financial support for this study included:

Source: EMR
Program: BDP
Proj. No: 5-7255
Value: \$17,584

Scientific Authority: I.B. Flann

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Energy, Mines and Resources Canada/CANMET



Bioenergy Fact Sheet

STUDIES SERIES

Effect of Fuel on Heat Harvester Performance

Principal Investigator

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Study Objectives

The objective of this project was to quantify the effect of various particulate wood fuels on the performance of a Heat Harvester TB500H wood chip combustion system fitted to a CTC hot water boiler. The University of New Brunswick, Department of Forest Engineering was the proponent for this study.

START DATE:	07/85
COMPLETION DATE:	01/86
APPLICABILITY:	
Commercial sector	Institutional sector
Residential	
TYPE OF BIOMASS:	
Forest crop for bioenergy	Forest waste/waste timber
Animal waste, manure	
TYPE OF TECHNOLOGY:	
Combustion (grate system)	
TOTAL STUDY COST:	\$35,000 (actual)

Background and Method

The Heat Harvester, rated at 175 kW, consists of a 0.6 cubic meter rectangular hopper, an insulated cylindrical stainless steel combustion chamber located beneath the hopper, a fuel feed system, forced-draft fan, an automatic fire extinguisher, and a control system. A port is provided at the bottom of the combustion chamber to connect an ash handling system. A thermocouple inside the combustion chamber is used to control a 400 W heating element to automatically ignite the fuel. When the temperature sensed by the thermocouple reaches a pre-test value, the ignition element is turned off, the combustion air fan is turned on, and the system runs until the demand for heat is satisfied. A second thermocouple senses the combustion chamber temperature which, if excessive, causes the fuel feed system to shut down until the temperature falls by about 100 degrees Celsius.

Effect of Fuel on Heat Harvester Performance

(continued)

Results

The Heat Harvester was sensitive to the quality of fuel used. The appliance tended to feed the normal, small chips from the hopper while retaining the small percentage of larger and twig-like pieces. Over time, if these irregular-sized pieces were not removed they became an increasing fraction of the total quantity of chips in the fuel hopper and formed a plug at the hopper exit which blocked the flow of normal chips. When this happened, the fire was lost and the unit shut down. In addition, the fuel feed auger would stall and the light weight auger flights on the Heat Harvester would bend. Either care must be taken in preparing a high quality fuel, or the appliance should be designed to handle the odd oversized or irregular-shaped fuel pieces without becoming damaged.

Non-combustible mineral material that accompanied the fuel chips tended to increase grate fouling. The mineral content in the ash also lowered the ash fusion temperature and caused an increase in clinker formation. The Heat Harvester was particularly affected by ash and mineral accumulations, even though it was equipped with an ash discharge port and associated ash handling system. Little or no ash was ever discharged from the ash discharge port in the combustion chamber during the test period. The ash tended to sinter into a large porous easily-crumbled cake-like mass that bridged over the ash discharge port. After about two weeks of operation this accumulation would almost totally block the discharge port of the combustion chamber. This resulted in combustion gases leaking back through the fuel supply system creating a light smoke in the house despite the operation of an induced draft fan. Temperatures in the Heat Harvester were also sufficiently high to cause clinkers to form which blocked some of the under-fire air inlets.

Publications

(1) C.A. Short, SIXTH CANADIAN BIOENERGY R&D SEMINAR, Evaluation of Four Wood-Chip-Fuelled Appliances for Residential Heating, University of New Brunswick, 1987, pp. 508-512.

(2) EFFECT OF FUEL CHARACTERISTICS ON THE PERFORMANCE OF A HEAT HARVESTER TB500H COMBUSTION SYSTEM, Bioenergy Development Program project no. 5-7047, Energy, Mines and Resources Canada, 1986.

Sources of outside financial support for this study included:

Source: EMR
Program: BDP
Proj. No: 5-7047
Value: \$35,000

Scientific Authority: I.B. Flann

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Energy, Mines and Resources Canada/CANMET



Bioenergy Fact Sheet

STUDIES SERIES

Heat Harvester Green Wood Chip Pre-Furnace

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Study Objectives

The study objective was to assess the performance of a Heat Harvester TB500H green wood chip combustion system. The appliance efficiency and its ability to cleanly burn fuel were to be determined and potential system modifications to improve appliance performance were to be identified. The University of New Brunswick, Department of Forest Engineering was the proponent for this study.

START DATE:	08/84
COMPLETION DATE:	03/87
APPLICABILITY:	
Commercial sector	Institutional sector
Residential	
TYPE OF BIOMASS:	
Forest crop for bioenergy	Forest waste/waste timber
Mill or factory waste	
TYPE OF TECHNOLOGY:	
Handling	Storage
Combustion(grate system)	
TOTAL STUDY COST:	\$44,998 (actual)

Background and Method

The Heat Harvester was designed to burn a range of fuels, including pulp-sized wood chips in either green or dry condition. The appliance is rated at 175 kW and consists of a 0.6 cu/m rectangular hopper, an insulated, horizontally-oriented cylindrical stainless steel combustion chamber located beneath the hopper, a fuel feed system, a forced-draft fan, an automatic fire extinguisher, and a control system. A port is provided at the bottom of the combustion chamber to connect an ash handling system. A variable speed motor drives two augers via roller chains to feed the fuel. The first auger, located in the bottom of the hopper, moves fuel towards the rear of the hopper and into a transfer box.

At the transfer box, the fuel drops about 400 mm to the second auger, which moves it forward into the combustion chamber. A thermocouple inside the combustion chamber is used to control a 400 W heating element which ignites the fuel. When the temperature sensed by the thermocouple reaches a pre-set value, the ignition element is turned off, the combustion air fan turned on, and the system runs until the demand for heat is satisfied. A second thermocouple senses combustion chamber wall temperature which, if excessive, causes the fuel feed system to shut down until the temperature falls by about 100 degrees Celsius.

Heat Harvester Green Wood Chip Pre-Furnace

(continued)

Results

The Heat Harvester failed to operate for long periods of time due to various problems. The appliance frequently failed to establish or to maintain a fire, and consequently its control system transferred the heating load to an electric boiler arranged to act as a back-up heater. As a result, overall system efficiency estimates are not available. At times when the unit was operating well, usually during periods of a few hours with test personnel in attendance, the appliance was able to deliver combustion efficiencies in a range between 65% and 75% and to achieve smoke numbers in the 0 to 5 range. A number of operating problems associated with the design of the Heat Harvester were identified. The flow of fuel in the hopper was poor and the mild steel used in the fuel delivery auger flights in the combustion chamber could not tolerate the temperatures involved.

Severe thermally-induced buckling and cracking of the stainless steel combustion chamber resulted due to the failure to allow for thermal expansion, making it difficult to control the fire because of the amount of combustion air which by-passed the fire altogether. In addition, the fuel ignition element was unreliable due to both an inability to withstand conditions in the combustion chamber and to uncertain detection of fire by the thermocouple in the combustion chamber used for its control. Operation of the burn-back fire extinguisher was not coupled with the control system; as a result, the ignition system could restart combustion without effective burn-back protection on a subsequent call for heat. The Heat Harvester, while suffering from some serious design flaws, does incorporate some good concepts. However, the appliance requires significant redesign and testing before being reoffered as part of a reliable heating system.

Publications

(1) C.A. Short, SIXTH CANADIAN BIOENERGY R&D SEMINAR, Evaluation of Four Wood-Chip-Fueled Appliances for Residential Heating, University of New Brunswick, 1988, pp. 508-512.

(2) C.A. Short, EVALUATION OF AND OPERATING EXPERIENCES WITH A GREEN CHIP PRE-FURNACE, Bioenergy Development Program project no. 4-6054, Energy, Mines and Resources Canada, 1988.

Sources of outside financial support for this study included:

Source: EMR
Program: BDP
Proj. No: 4-6054
Value: \$44,998

Scientific Authority: I.B. Flann

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Energy, Mines and Resources Canada/CANMET



Bioenergy Fact Sheet

STUDIES SERIES

Compendium of Energy-From-Waste Technologies

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Study Objectives

The objective of this project is to compile and produce a state-of-the-art data book documenting the options available for disposal of municipal solid waste (MSW), both with and without energy recovery. This book will draw heavily on previous MSW studies, and include cost and performance data on conversion equipment, fuel preparation requirements and pollution control strategies. The aim of the study is to equip planners and engineers with a convenient tool for system design and decision-making, as well as provide a compendium of useful information for any other interested parties, such as municipal governments, consultants, funding agencies and citizens groups. B.H. Levelton and Associates Ltd. is the proponent for this study.

START DATE: 02/89

COMPLETION DATE: 08/90

APPLICABILITY:

Institutional sector

TYPE OF BIOMASS:

Municipal solid waste

TYPE OF TECHNOLOGY:

Handling	Combustion(grate system)
Fluidized bed combustion	Fixed bed gasification
Fluidized bed gasification	Landfill gas system

TOTAL STUDY COST:	\$75,624 (estimated)
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Background and Method

The study will first present some basic information and statistics on the production and handling characteristics of MSW before detailing each of the available disposal technologies. These technologies include incineration, pyrolysis, composting, gasification and landfill gas recovery. A detailed summary of pollution control requirements and health risks is to be included for each of the above.

A thorough search of the available published literature on MSW disposal/utilization is expected to provide the bulk of material submitted in this report. Recent studies by the U.S. EPA (1987), Lavalin (1987) and SNC (1987) will provide a core of published material, as well as much of the technical data.

Standards are developed for the presentation of information on each of the MSW disposal technologies, including capital cost, performance characteristics, maintenance costs and manpower requirements. Site visits will be made to operating MSW facilities such as the mass-burn incinerator in Burnaby, B.C., as part of the study.

Compendium of Energy-From-Waste Technologies

(continued)

Results

A comprehensive literature search has been conducted to identify information that should be included in the report. Work is progressing with the assembly and reviews of available reports, papers and other information.

Publications

Sources of outside financial support for this study included:

Source: EMR
Program: BDP
Proj. No: 8-9038
Value: \$75,624

Scientific Authority: J. M. Charron

Funding for R&D supported by the Bioenergy Development Program (BDP) was provided by the Interdepartmental Panel on Energy R&D (PERD).

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580 Booth Street, Ottawa K1A 0E4.

Energy, Mines and Resources Canada/CANMET



Bioenergy Fact Sheet

STUDIES SERIES

Process Heat and Manganese from Peat

Principal Investigator

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Study Objectives

The primary objective of this study was to burn thermal and manganese peat samples in a bench-scale circulating fluidized-bed combustor (CFBC) at the Research and Productivity Council in Fredericton, New Brunswick, in order to assess their thermal performance. Neither of these peat types are currently utilized in the province. A secondary objective was to determine the potential for commercial manganese recovery from the manganese peat. The Research and Productivity Council was the proponent for this project.

START DATE: 02/87

COMPLETION DATE: 04/87

APPLICABILITY:

Industrial sector

TYPE OF BIOMASS:

Peat

TYPE OF TECHNOLOGY:

Cleaning

Fluidized bed combustion

Fluidized bed combustion

Dewatering/Drying

Fluidized bed combustion

TOTAL STUDY COST: \$65,478
(actual)

Background and Method

The most common use for peat in New Brunswick is horticultural. However, much of the estimated 21 million tonnes of reserves are considered unsuitable for horticulture due to the peat's high degree of decomposition. The heating value of thermal peat (at 50% moisture content (MC)) is estimated at 15 MJ/kg, and with its low ash and sulphur content, it is considered an ideal fuel. Manganese peat has a much higher ash content which contains large quantities of manganese. The heating value of manganese peat is approximately 1.2 MJ/kg. In this project, peat samples are prepared which are combusted under controlled conditions. Representative samples of manganese peat are dried from 80% MC to around 22%, then sieved to a particle size of less than 3 mm. Thermal peat is also sieved to a similar size, but does not require drying. Combustion takes place in a 5.8 m high steel cylinder, of 12.7 cm diameter, which contains 200 kg of silica sand and which is preheated to 850 degrees Celsius.

The peat and air feed rates are adjusted to control the amount of oxygen available for combustion; thermal peat is burned in an oxidizing atmosphere with a measured flue gas oxygen content of 2.5%, while the manganese peat is combusted under reducing conditions to produce an ash from which manganese can be extracted. The CFBC operates at higher gas velocities than the more common bubbling fluid-bed combustors. It recirculates large quantities of solids back into the combustion chamber from a primary cyclone and standpipe, leading to an effective circulation of silica sand and fuel particles. On-line analyzers and sensors are available to monitor the temperature and composition of flue gases, allowing researchers to optimize combustion conditions.

Process Heat and Manganese from Peat

(continued)

Results

One combustion test with thermal peat was performed under steady-state conditions over a 68-hour period, while 6-and 4-hour tests were run with the manganese peat samples.

Combustion of thermal peat in the CFBC was successful: there were no operational problems, and results showed a carbon conversion efficiency of 98.8% at an excess air level of 13.5%. The main difference noted between burning this fuel and burning coal or oil shale was the need to feed additional inert material (silica sand) into the combustor to replace that lost to attrition.

The high moisture content of thermal peat (40%) was likely responsible for the development of a temperature gradient inside the combustor, with the temperature at the top of the unit being 70 degrees Celsius higher than at the bottom, where fuel is fed in. Water absorbs large amounts of heat when vaporized.

The manganese peat achieved a carbon conversion efficiency of 94.7% under reducing conditions, although the level of CO produced, at 4.3%, was high. Analysis of the manganese peat ash showed a manganese content of 18%, representing a threefold increase in concentration when compared to the peat feed. Combustion may therefore be a viable method of concentrating manganese in solids for future extraction, though further study and economic analysis will be needed to confirm this.

Publications

(1) P.F. Salib, Peat Energy for Process and Manganese Production, SEVENTH CANADIAN BIOENERGY R&D SEMINAR, Research and Productivity Council, 1989, pp. 575.

(2) P.F. Salib and R. Robson, PEAT ENERGY FOR PROCESS HEAT AND MANAGEMENT PRODUCTION, Bioenergy Development Program project no. 6-6286, Energy, Mines and Resources Canada, 1987.

Sources of outside financial support for this study included:

Source: EMR
Program: BDP
Proj. No: 6-6286
Value: \$65,478

Scientific Authority: J.E. Robert

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Energy, Mines and Resources Canada/CANMET



Bioenergy Fact Sheet

STUDIES SERIES

Energy Recovery from Pulp Mill Sludges

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Study Objectives

Research is underway to study the combustion characteristics of pulp mill sludges in a circulating fluidized-bed combustor (CFBC). Work will be performed at the Research and Productivity Council lab in Fredericton, New Brunswick, using sludge samples from the nearby Miramichi Pulp and Paper Company. It is hoped that operational problems associated with sludge burning in conventional boilers (tube fouling, aggravated clinker formation, excess humidity) can be reduced or eliminated with this new combustion technology. Results from the study will be used in a preliminary economic assessment of pulp mill sludge combustion.

START DATE: 03/89

COMPLETION DATE: 05/90

APPLICABILITY:

Industrial sector

TYPE OF BIOMASS:

Mill or factory waste

TYPE OF TECHNOLOGY:

Fluidized bed combustion

TOTAL STUDY COST: \$122,093
(estimated)

Background and Method

The Canadian pulp and paper industry produces over 2200 tonnes of dry sludge each day from its waste water treatment operations, of which just over half is burned and, the rest is landfilled. Virtually all of the incinerated portion is currently fired in combination fuel/hog boilers as a small percentage of the total feed.

This project will use circulating fluidized-bed combustor technology, which is ideally suited to burning low heating value and high moisture content fuels. The low (900 degrees Celsius) operating temperature of the unit greatly reduces the probability of ash fusion and clinker formation.

Work is aimed at assessing the combustion characteristics of two kinds of sludge -- fresh and aged -- which will be burned separately and in combination with supplementary fuels (in this case Minto coal and N.B. shale). Eight tests of 12-to-24-hour duration are planned, and during each run combustion gases will be monitored for SO_x, NO_x and CO emissions, to determine the environmental impact of the process. All ash products will be examined for signs of slagging or potential disposal problems, and a mass/energy balance will be produced for each of the runs to determine the combustion efficiency and potential energy recovery.

Energy Recovery from Pulp Mill Sludges

(continued)

Results

The project is progressing well. A feeding system has been developed and tests will begin shortly. There are no study results at this point in time.

Publications

(1) P.F. Salib, Circulating Fluidized Bed Combustion of Pulp Mill Sludges, SEVENTH CANADIAN BIOENERGY R&D SEMINAR, Research and Productivity Council, 1989, pp. 581.

Sources of outside financial support for this study included:

Source: EMR
Program: BDP
Proj. No: 8-9056
Value: \$122,093

Scientific Authority: J.E. Robert

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Energy, Mines and Resources Canada/CANMET



Bioenergy Fact Sheet

STUDIES SERIES

Comparative Study of Fluid-Bed Combustors

Principal Investigator

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Study Objectives

The objective of this study was to compare technical and economic parameters of presently available small-scale wood-waste-fired atmospheric fluidized-bed combustors and compare them to conventional hog fuel boilers of similar capacity. The future trends for fluidized-bed combustion systems in the 0-to-27,000 kg/h capacity range were also examined. Sandwell Swan Wooster Inc. was the proponent for this study.

START DATE:	02/85
COMPLETION DATE:	03/86
APPLICABILITY:	
Industrial sector	Commercial sector
TYPE OF BIOMASS:	
Not specific to a type of biomass	
TYPE OF TECHNOLOGY:	
Fluidized bed combustion	
TOTAL STUDY COST:	\$87,181 (actual)

Background and Method

Increased utilization of wood waste has contributed to the appearance of a greater diversity of biomass combustion equipment on the market, often making the selection of an appropriate combustion system difficult. To address this information gap, Sandwell conducted a comprehensive study to compare the technical parameters, operating problems, and capital costs of atmospheric fluidized-bed combustors and conventional wood-waste boilers. Systems were evaluated for small industrial and commercial plants to a steam generating capacity of 27,000 kg/h.

Comparative data were compiled through a literature survey and site visits were conducted to operating fluidized-bed combustion systems.

Comparative Study of Fluid-Bed Combustors

(continued)

Results

The study determined that the selection of an atmospheric fluidized-bed boiler or a conventional hog fuel boiler may depend on the moisture content of the fuel. For moisture contents below 50-55%, the small atmospheric fluidized-bed boiler is more attractive than the conventional hog fuel boiler because less fuel preparation is required, better combustion control is attained and the units have lower capital costs. However, the conventional hog-fuel-fired boiler which can be designed to burn wood waste with moisture contents up to 65% is the better option for fuels with over 55% moisture content.

Biomass-waste-fired atmospheric fluidized-bed units cost 19-25% less than conventional hog fuel boilers, while operating costs are essentially the same. Among the many types of small atmospheric fluidized-bed boilers, units with in-bed tubes are the best option because the turn down ratio compares favourably with conventional hog-fuel-fired boilers, and their operating costs are marginally lower than for either fluidized-bed combustors or hog fuel boilers.

In North America, most of the bubbling-bed combustors burning wood waste do not have in-bed tubes. The trend over the next decade for this size of plant will be to develop conventional bubbling beds with in-bed tubes to generate lower operating costs.

Publications

(1) C. MacCallum and E. Constantin, Small Fluidized Bed Boilers Have the Edge, SIXTH CANADIAN BIOENERGY R&D SEMINAR, Sandwell Swan Wooster Inc., 1988, pp. 485-489.

(2) TECHNO-ECONOMIC ANALYSIS OF SMALL-SCALE FLUIDIZED-BED COMBUSTORS, Bioenergy Development Program project no. 4-6367, Energy, Mines and Resources Canada, 1986.

Sources of outside financial support for this study included:

Source: EMR
Program: BDP
Proj. No: 4-6367
Value: \$87,181

Scientific Authority: J.E. Robert

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For further information, contact the Efficiency and Alternative Energy Technology Branch, EMR Canada 580 Booth Street, Ottawa, K1A 0E4.

Energy, Mines and Resources Canada/CANMET



Bioenergy Fact Sheet

STUDIES SERIES

Energy Recovery from Coke Dust

Principal Investigator

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Study Objectives

This project will study the feasibility of burning residual coke dust in a circulating fluidizing-bed combustor. This is part of a larger program being carried out by the municipal government of Le Fjord-du-Saguenay to update and integrate industrial and municipal solid waste (MSW) treatment in their region. The optimum conditions for carbon dust combustion will be determined, and a cost-benefit analysis will assess potential commercial applications. UNIGEC is the proponent for this study.

START DATE: 02/89

COMPLETION DATE: 01/90

APPLICABILITY:

Industrial sector

TYPE OF BIOMASS:

Municipal solid waste

See text

TYPE OF TECHNOLOGY:

Fluidized bed combustion

TOTAL STUDY COST:

\$94,970
(estimated)

Background and Method

The Alcan aluminium smelter in Jonquiere annually produces over 10,000 tonnes of carbon dust from the calcination of coal in rotary ovens. Aluminium electrolysis requires carbon anodes, and these are manufactured via calcination, a heating process which drives off all volatiles. The coke dust, which is removed by scrubbers, is almost pure solid carbon. Without any volatile fraction to help sustain combustion, the solid carbon is difficult to burn and requires very high temperatures.

The research is being carried out by UNIGEC in collaboration with UQAC (the University of Quebec at Chicoutimi) who will undertake a theoretical study of the incineration process. All relevant literature dealing with waste management technology will be catalogued and reviewed, and a report will be generated which outlines the best options available to the municipality for installing a comprehensive waste management facility.

The second part of this project involves analyzing samples of the carbon dust and testing its combustion properties. The dust has a heating value of around 35 MJ/kg, and due to its fineness seems best suited to a circulating fluidized-bed combustion system. A comprehensive series of tests at the Canadian Combustion Research Laboratory of Energy, Mines and Resources in Ottawa will provide information on optimum temperatures, feed rates, combustion products and other incineration parameters. It is then proposed to design and build a small-scale combustor to test the theoretical model.

Energy Recovery from Coke Dust

(continued)

Results

The project is progressing as planned. Preliminary combustion tests indicate the carbon dust burns better than expected.

If successful, the results of the carbon combustion tests may be applicable to the coke and petroleum industries which face similar disposal problems for their carbon-rich residues. The energy potential from such residues would be even greater than that from the aluminum smelting operations.

Publications

Sources of outside financial support for this study included:

Source: EMR
Program: BDP
Proj. No: 8-6178
Value: \$79,970

Scientific Authority: J. M. Charron

Funding for R&D supported by the Bioenergy Development Program (BDP) was provided by the Interdepartmental Panel on Energy R&D (PERD).

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For further information, contact the Efficiency and Alternative Energy Technology Branch, EMR Canada, 580 Booth Street, Ottawa, K1A 0E4.

Energy, Mines and Resources Canada/CANMET



Bioenergy Fact Sheet

STUDIES SERIES

Wood Waste Cogeneration Unit for Sawmills

Principal Investigator

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Study Objectives

The objective of the Phase I Feasibility study was to develop the concept of a cost-effective wood-waste-fuelled, indirectly-fired gas turbine cogeneration system to generate electricity and dry kiln heat for sawmills. The Phase II Engineering study objective was to advance the work completed in Phase I in such a way that industrial participants could be attracted to a demonstration project. The overall objective of Phase III Site evaluation is to identify and rank prospective sites for a demonstration project of the sawmill cogeneration system studied in Phases I and II, and to structure a project for the best site.

START DATE:	06/87
COMPLETION DATE:	12/89
APPLICABILITY:	Industrial sector
TYPE OF BIOMASS:	Mill or factory waste
TYPE OF TECHNOLOGY:	Fluidized bed combustion Combustion (suspension)
TOTAL STUDY COST:	\$156,275 (estimated)

Background and Method

Although most sawmills generate more than enough wood waste to be self-sufficient in both dry kiln heat and electricity requirements, it is not generally financially viable to use conventional steam/electricity cogeneration systems at the sawmill scale of operation. The overall objective of this project was therefore to develop a cost-effective wood waste-fired power generation and dry kiln heating system for sawmill applications.

Research, design and development of the system was planned in a number of phases. An engineering design and financial evaluation were prepared for an innovative type of cogeneration system in Phase I of the project. Favorable results from Phase I led to the initiation of Phase II, which was the advancement of the generic design of Phase I by preparing a preliminary engineering design and financial analysis of the system for a specific demonstration site.

A number of alternative system configurations were identified and preliminary engineering designs prepared for each.

The major tasks of Phase III are the identification of a short list of suitable sites and industrial participants, identification of funding alternatives, evaluation of the sites and the structuring of a demonstration project.

Wood Waste Cogeneration Unit for Sawmills

(continued)

Results

In the context of the system design, preliminary engineering, and budget prices, Canadian Resourcecon Ltd. has determined that the indirectly-fired cogeneration approach is technically and economically sound. The cogeneration system proposed could, at a commercial scale of operation, result in a sawmill being completely energy self-sufficient. All of the heat required for lumber drying, as well as all of the electricity required by the mill, could be provided by wood waste which is currently either land-filled or incinerated.

One of the key technical problems, a workable combustor/air heater arrangement, appears to be successfully addressed by the combined unit quoted by Applied Thermal Systems. The projected financial data for a commercial scale of operation are also encouraging.

A successful demonstration project could result in the widespread adoption of cogeneration in sawmills both in Canada and abroad, particularly in developing countries where the financial return would be substantially higher.

Publications

(1) WOOD-WASTE-FUELLED INDIRECTLY-FIRED GAS TURBINE COGENERATION PLANT FOR SAWMILL APPLICATIONS, PHASE II: Site-Specific Preliminary Engineering and Financial Analysis, Bioenergy Development Program project no. 7-6038, Energy, Mines and Resources Canada, 1988.

(2) SIXTH CANADIAN BIOENERGY R&D SEMINAR, Wood-Waste-Fuelled, Indirectly-Fired Gas Turbine Cogeneration Plant for Sawmill Applications - Phase I, Canadian Resourcecon Ltd., 1988, pp. 494-496.

(3) M.S. Sinclair and R.L. Evans, SEVENTH CANADIAN BIOENERGY R&D SEMINAR, Wood Waste Fuelled, Indirectly Fired Gas Turbine Cogeneration Plant for Sawmill Applications, Canadian Resourcecon Ltd., 1989, pp. 597.

Sources of outside financial support for this study included:

Source:	EMR	EMR	EMR
Program:	BDP	BDP	BDP
Proj. No:	6-6120	7-6038	8-6058
Value:	\$40,450	\$79,852	\$36,000

Scientific Authority: J.M. Charron

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Energy, Mines and Resources Canada/CANMET



Bioenergy Fact Sheet

STUDIES SERIES

Tall Oil As Fuel For Kraft Pulp Industry

Principal Investigator

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Study Objectives

The study objective for project 3-6140 (ENFOR C-390) was to assess the technical feasibility of using tall oil, in its crude or upgraded form, as a diesel substitute for the operation of mobile equipment. In Phase I (4-6109), emphasis was placed on assessing engine endurance over the longer-term and developing a means to increase the service life of the fuel injection system. In Phase II, Part I (4-6311), the emphasis was also put on long-term endurance, specifically using upgraded tall oil fuels to confirm that dewatered tall oil substantially reduces fuel injection pump corrosion. Weyerhaeuser Canada, formerly Prince Albert Pulp Company Ltd., of Saskatchewan was the proponent for this study.

START DATE: 05/83

COMPLETION DATE: 11/86

APPLICABILITY:

Industrial sector

Agricultural sector

TYPE OF BIOMASS:

Forest crop for bioenergy

Mill or factory waste

TYPE OF TECHNOLOGY:

Combustion

TOTAL STUDY COST: \$173,626
(actual)

Background and Method

Tall oil soap is a by-product of Kraft pulping. During the pulping operation, fatty and rosin acids produced in the tree are saponified by the pulping (white) liquor. The soap is washed from the pulp in brown stock washers, and is carried with the black liquor to the evaporators. Soap can then be recovered from partially evaporated black liquor and reacted with acid to yield crude tall oil, lignin and spent acid. The crude tall oil may then be separated from the lignin and spent acid by means of gravity or centrifugal separation. The precipitated lignin and spent acid are then neutralized and returned to the mill's recovery system. In situations of fluctuating market demand for tall oil, it is highly desirable for a mill to have other profitable uses for it. Moreover, if tall oil is adapted for use in mobile diesel equipment, a pulpmill could be made to achieve a high degree of energy self-sufficiency for its woodlands operations. Diesel, dewatered tall oil/diesel fuel blends and tall oil fatty acids (TOFA)/diesel fuel blends were prepared and tested in order to evaluate the potential of tall oil as a diesel alternative.

All engine testing was performed on a 25kW air-cooled, direct injection, Deutz model F2L 912 diesel engine. The fuel consumption, engine speed and torque, and various temperatures were monitored. The testing program consisted of 2 major long-term tests. The first involved a 100-hour break in period using 100% summer-grade diesel and a 580-hour test with a blend of 50% dewatered tall oil and 50% diesel. The second long-term test involved a 100-hour break in period using 100% summer-grade diesel and a 1570-hour test using a blend of 50% tall oil fatty acids and 50% summer grade diesel. The fuel injectors were serviced as required. Crankcase oil samples were taken at 20-hour intervals during each of the tests, and were analyzed at Federated Co-operative Refineries Limited for wear metals and lubricant additives content. After each long-term test, the engine was completely disassembled, inspected for signs of wear or corrosion, and subsequently rebuilt.

Tall Oil As Fuel For Kraft Pulp Industry

(continued)

Results

The results of this study indicate that fuel blends containing tall oil contribute to short fuel injector life. The fuel injectors repeatedly failed after 300-400 hours of operation on tall oil fuels. This failure was due to a combination of fouling of the injector tip with carbon deposits and of corrosion around the injector fuel port holes. The fuel injector problem lead to higher than normal engine wear/corrosion and to increased combustion chamber deposits. It was felt that the major cause of the bearing wear/corrosion is lubrication oil breakdown, caused by fuel related contamination of the lubricating oil. The combustion chamber deposits were also found to be mostly fuel related. While the deposits did not directly affect engine performance over the length of the tests (up to 1570 hours), a continued buildup resulted in excessive piston, ring and cylinder wear. Both of these problems were felt to be the result of fuel injector build up/failure.

Under the current price structure, the tall oil fuels are not economically viable. While the cost of crude tall oil is roughly 1/3 to 1/2 that of diesel, the inherent cost of processing, distribution, and increased engine maintenance negate this price differential. However, if the production of dewatered tall oil for fuel was integrated with tall oil fractionation for conventional markets, an economic advantage may exist. Moreover, the sale of tall oil fatty acids is often the limiting factor to the production output of tall oil fractionators. As a result, an alternate outlet for this material may prove to be very valuable.

Publications

(1) R. Secor, L. Lewko, FIFTH CANADIAN BIOENERGY R&D SEMINAR, Tall oil as a Fuel for Mobile Equipment in the Kraft Pulp Industry, Weyerhaeuser Canada, 1984, pp. 526-530.

(2) R.J. Secor, L.A. Lewko, TALL OIL AS A FUEL FOR MOBILE EQUIPMENT IN THE KRAFT PULP INDUSTRY, Bioenergy Development Program project no. 3-6140, ENFOR C-390, Energy Mines and Resources Canada, 1983.

(3) L.A. Lewko, W.B. Reed, R.J. Secor, TALL OIL AS FUEL FOR MOBILE EQUIPMENT IN THE KRAFT PULP INDUSTRY PHASE II, Bioenergy Development Program project no. 4-6109, Energy, Mines and Resources Canada, 1984.

(4) L.A. Lewko, W.B. Reed, R.J. Secor, TALL OIL AS FUEL FOR MOBILE EQUIPMENT IN THE KRAFT PULP INDUSTRY PHASE II - PART II, Bioenergy Development Program project no. 4-6311, Energy, Mines and Resources Canada, 1986.

Sources of outside financial support for this study included:

Source:	EMR	EMR	EMR
Program:	ENFOR C-390	BDP	BDP
Proj. No:	3-6140	4-6109	4-6311
Value:	\$20,000	\$57,772	\$95,854

Scientific Authority: Dr. A.J. Dolenko

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Energy, Mines and Resources Canada/CANMET

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